PREFACE

TO

THE TWENTY-SECOND EDITION

In presenting this edition I wish to acknowledge my indebtedness :

To Professor Edward Fawcett of the University of Bristol, who allowed me to make drawings of his model of the chondrocranium of a 27 mm. human embryo, and who revised the description of the development of the skull on pp. 71 to 76.

To Professor S. Ernest Whitnall of Macgill University, Montreal, who permitted me to copy some illustrations from his book on *The Anatomy of the Human Orbit*.

To my colleagues in the Department of Physiology, Professor David Burns and Dr. G. Albert Clark ; the former revised the histological part of the book, and the latter supplied a number of microscopic specimens for purposes of illustration.

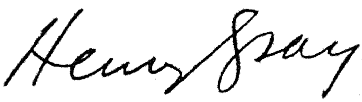
To Dr. C. M. Smithies, one of my former assistants, who prepared many of the dissections required for the new figures, and to Dr. R. Bramble Green, my present senior assistant, who helped to correct the proof-sheets of the book.

The new illustrations—about sixty in number—have been prepared from drawings made by Mr. Sydney A. Sewell.

R. HOWDEN.

University of Durham College of Medicine,
Newcastle-upon-Tyne, *June*, 1923.

HENRY GRAY, F.R.S., F.R.C.S.



As the readers of Gray's *Anatomy* may be interested to learn something of its original author, Henry Gray, the following information as to his career has been extracted from an article which appeared in the *St. George's Hospital Gazette* of May 21st, 1908.

Gray, whose father was private messenger to George IV. and also to William IV., was born in 1827, but of his childhood and early education nothing is known.

On the 6th of May, 1845, he entered as a perpetual student at St. George's Hospital, London, and he is described by those who knew him as "a most painstaking and methodical worker, and one who learnt his anatomy by the slow but invaluable method of making dissections for himself."

While still a student he secured, in 1848, the triennial prize of the Royal College of Surgeons for an essay entitled, "The origin, connexions and distribution of the nerves to the human eye and its appendages, illustrated by comparative dissections of the eye in other vertebrate animals."

At the early age of twenty-five he was, in 1852, elected a Fellow of the Royal Society, and in the following year he obtained the Astley Cooper prize of three hundred guineas for a dissertation "On the structure and use of the spleen."

He held successively the posts of demonstrator of anatomy, curator of the museum, and lecturer on anatomy at St. George's Hospital, and was in 1861 a candidate for the post of assistant-surgeon. Unfortunately he was struck down by an attack of confluent smallpox, which he contracted while looking after a nephew who was suffering from that disease, and died at the early age of thirty-four. A career of great promise was thus untimely cut short. Writing on June 15th, 1861, Sir Benjamin Brodie said, "His death, just as he was on the point of obtaining the reward of his labours . . . is a great loss to the Hospital and School."

In 1858 Gray published the first edition of his *Anatomy* which covered 750 pages and contained 363 figures. He had the good fortune to secure the help of his friend, Dr. H. Vandyke Carter, a skilled draughtsman and formerly a demonstrator of anatomy at St. George's Hospital. Carter made the drawings from which the engravings were executed, and the success of the book was, in the first instance, undoubtedly due in no small measure to the excellence of its illustrations. A second edition was prepared by Gray and published in 1860.

The portrait here given of Gray is a reproduction of one which appeared in the *St. George's Hospital Gazette* of May 21st, 1908, where the original is described as being "a very faded photograph taken by Mr. Henry Pollock, second son of the late Lord Chief Baron Sir Frederick Pollock, and one of the earliest members of the photographic society of London."

R. H.

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CORRIGENDA

Page 163, line 8, for 'oxeskeleton' read 'exoskeleton.'

„ 253, line 6, for 'Sternoc leidomastoideus' read 'Sternocleidomastoideus.'

„ 618, par. 3, line 3, for 'temporomandibular' read 'mandibular.'

„ 690, par. 2, line 9, for 'abductor' read 'adductor.'

„ 877, par. 5, line 2, for 'meniages' read 'meninges.'

HUMAN ANATOMY

INTRODUCTION

THE term *human anatomy* comprises a consideration of the various structures which make up the human organism. In a restricted sense it deals merely with the parts which form the fully developed individual and which can be rendered evident to the naked eye by various methods of dissection. Regarded from such a standpoint it may be studied by two methods: (1) the various structures may be separately considered—*systematic anatomy*; or (2) the organs and tissues may be studied in relation to one another—*topographical* or *regional anatomy*.

It is, however, of much advantage to add to the facts ascertained by naked-eye dissection those obtained by the use of the microscope. This introduces two fields of investigation, viz. the study of the minute structure of the various component parts of the body—*histology*; and the study of the human organism in its immature condition, i.e. the various stages of its intra-uterine development from the fertilised ovum up to the period when it assumes an independent existence—*embryology*. Owing to the difficulty of obtaining material illustrating all the stages of this early development, gaps must be filled up by observations on the development of lower forms—*comparative embryology*, or by a consideration of adult forms in the line of human ancestry—*comparative anatomy*. The direct application of the facts of human anatomy to the various pathological conditions which may occur constitutes the subject of *applied anatomy*. Finally, the identification of structures on or immediately underlying the surface of the body is frequently made the subject of special study—*surface anatomy*.

SYSTEMATIC ANATOMY.—The various systems of which the human body is composed are grouped under the following headings:

1. *Osteology*—the bony system or skeleton.

2. *Syndesmology*—the articulations or joints.

3. *Myology*—the muscles. With the description of the muscles it is convenient to include that of the fasciæ which are so intimately connected with them.

4. *Angiology*—the vascular system, comprising the heart, blood-vessels, lymphatic vessels and lymph-glands.

5. *Neurology*—the nervous system. The organs of the senses may be included in this system.

6. *Splanchnology*—the visceral system. Topographically the viscera form two groups, viz. the thoracic viscera and the abdominopelvic viscera. The heart, a thoracic viscus, is best considered with the vascular system. The rest of the viscera may be grouped according to their functions: (*a*) the *respiratory apparatus*; (*b*) the *digestive apparatus*; and (*c*) the *urogenital*

apparatus. Strictly speaking, the third sub-group should include only such components of the urogenital apparatus as are included within the abdomino-pelvic cavity, but it is convenient to study under this heading certain parts which lie in relation to the surface of the body, e.g. the testes and the external organs of generation.

For descriptive purposes the body is supposed to be in the erect posture, with the arms hanging by the sides and the palms of the hands directed forwards. The *median plane* is a vertical anteroposterior plane, passing through the centre of the trunk. This plane will pass approximately through the sagittal suture of the skull, and hence any plane parallel to it is termed a *sagittal plane*. A vertical plane at right angles to the median plane passes, roughly speaking, through the central part of the coronal suture or through a line parallel to it ; such a plane is therefore known as a *coronal plane*. A plane at right angles to both the median and frontal planes is termed a *transverse* or *horizontal plane*.

The terms *anterior* or *ventral*, and *posterior* or *dorsal*, are employed to indicate the relation of parts to the front or back of the body or limbs, and the terms *superior* or *cephalic*, and *inferior* or *caudal*, to indicate the relative levels of different structures ; structures nearer to or further from the median plane are referred to as *medial* or *lateral* respectively.

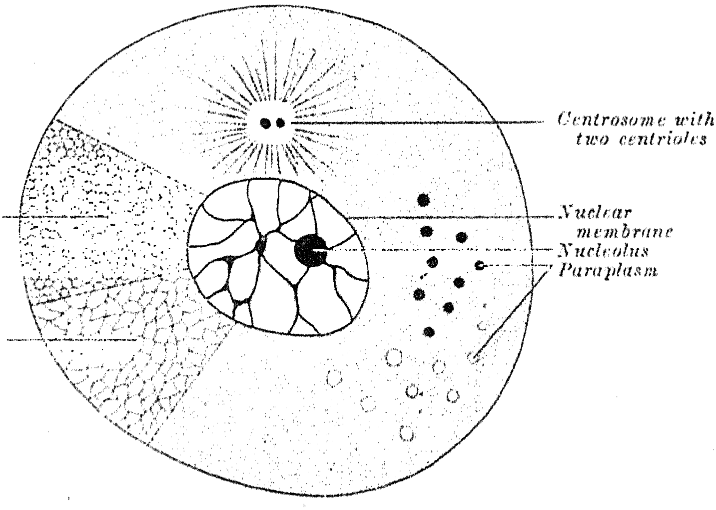
The terms *superficial* and *deep* are strictly confined to descriptions of the relative depth from the surface of the various structures : *external* and *internal* are reserved almost entirely for describing the walls of cavities or of hollow viscera. In the case of the limbs the words *proximal* and *distal* refer to the relative distance from the attached end of the limb.

HISTOLOGY

THE ANIMAL CELL

ALL the tissues and organs of the body originate from the fertilised ovum, a microscopic structure consisting of a jelly-like material enclosed in a membrane, and containing a small, spherical, more solid body in its interior; the contained body is called a nucleus, and within it are found one or two smaller bodies, termed nucleoli (fig. 1). The fertilised ovum divides and subdivides into an enormous number of similar structures, which are known as *cells*, and these become variously modified according to the function which they have to perform. Although the cells of the different tissues and organs vary considerably in shape, size, and other characteristics, each consists of a semi-fluid material, known as protoplasm, and contains a nucleus (fig. 1). A cell may therefore be defined as "a mass of protoplasm containing a nucleus." But this definition is not altogether satisfactory, because some cells (the red blood-corpuscles of mammals) are destitute of nuclei, while others (*e.g.* protozoa) may be multinucleated.

FIG. 1.—A diagram of a cell.



Protoplasm varies in composition, but in all cases it yields, on analysis, nitrogenous substances, known as proteins. When examined with high powers of the microscope it may appear homogeneous, but many cells show some degree of differentiation into fibrils or granules. After fixation with reagents, such as mercuric chloride, most cells exhibit a reticular, or, rather, a sponge-like structure, which has a greater affinity for dyes than the material contained in its meshes. It was formerly believed that living protoplasm had a similar structure, and consisted of a fibrillar network, or *spongioplasm*, with a more fluid material, or *hyaloplasm*, in its interstices. The view most commonly held at the present time, however, is that the large molecules of which protoplasm is composed are so arranged as to form two distinct 'phases.' The result is a structure resembling foam, and consisting of minute spaces containing fluid material and bounded by a less fluid phase

formed by a closer aggregation of the molecules. Whether this view be correct or not, it is convenient in the meantime to retain the terms spongioplasm and hyaloplasm to indicate the structure seen in the fixed and stained cell.

The protoplasm of cells frequently contains granules of foreign material, such as glycogen, fat, or pigment. These may have been either formed in the cell or taken in from without, and are spoken of as *paraplasm* or *deuteroplasm*.

Few animal cells resemble the ovum in possessing a definite cell-membrane: in those which do not, the surface exhibits certain physical properties which point to a local condensation of some of the protoplasmic constituents. According to Overton these are of a fatty nature and are known as lipoids.

The **nucleus**, in fixed and stained preparations, exhibits a differentiation into a network, or *karyomitome*, and a more fluid material, or *karyoplasm*, in the meshes of the network. The karyomitome is condensed at the periphery of the nucleus to form a well-defined wall, the *nuclear membrane*, and consists of particles of a substance, called *chromatin* because of its affinity for basic dyes, imbedded in a homogeneous material, *linin*, which stains with acid dyes. The staining properties of chromatin are due to the presence of nucleic acid.

The **nucleolus** is a small, spherical, highly refracting body, which stains with acid dyes. Nodes of the chromatin network are liable to be mistaken for nucleoli, but may be distinguished by their irregular shape and staining affinities; they are known as *pseudonucleoli*.

A **centrosome** is present in most cells. It lies near the nucleus, and consists of a spherical area of clear protoplasm, in the middle of which is a minute spot or *centriole*; the latter plays an important part in cell-division. The threads of the protoplasmic reticulum immediately around the centrosome become radially arranged and diverge from it like the rays of the conventional sun.

Two other groups of bodies are of very general occurrence in cells, viz. (*a*) chondriosomes or mitochondria, and (*b*) the reticular apparatus of Golgi; little is known, however, as to their nature or function. *Chondriosomes*, first described in germ-cells undergoing development into spermatozoa, consist of granules, rods or vesicles grouped in the neighbourhood of the nucleus. When the cell divides they are distributed between the two daughter cells. The *reticular apparatus* of Golgi, first described in nerve-cells, comprises a network or group of rods in the protoplasm immediately surrounding the centrosome. During cell-division the network divides into rods which are distributed between the two daughter cells.*

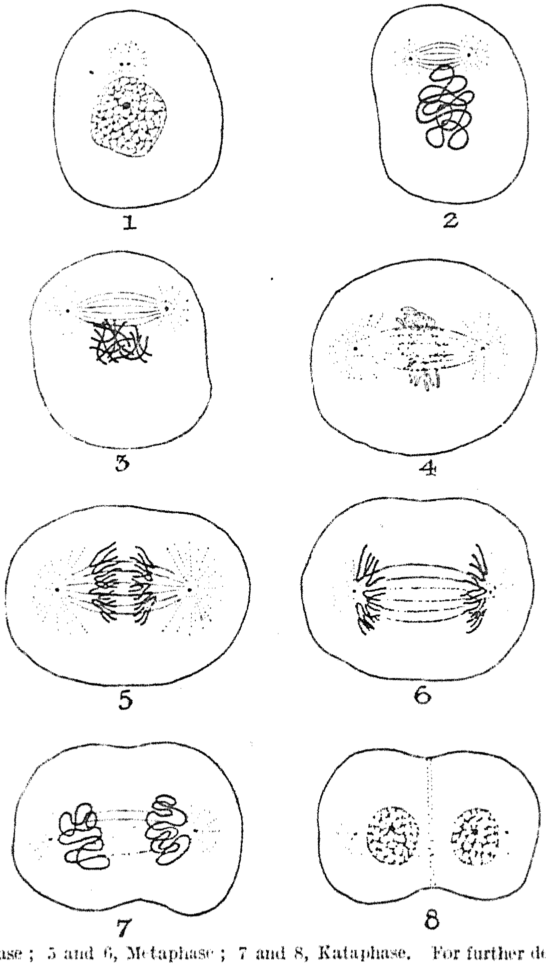
Reproduction of cells is effected either by *direct* or by *indirect division*. In *direct division* (*amitosis*) the nucleus becomes constricted in the middle, assuming an hourglass shape, and then divides into two. This is followed by a cleavage or division of the whole protoplasmic mass of the cell; and thus two daughter cells are formed, each containing a nucleus. The daughter cells are at first smaller than the original mother cell; but they grow, and the process may be repeated in them, so that multiplication may take place rapidly. Direct division is said to occur in leucocytes and bone-cells, and in the epithelial cells lining the bladder. *Indirect division* or *karyokinesis* (*mitosis*) is the common method of division in the higher animals, and the process is characterised by a series of complex changes in the nucleus, leading to its subdivision; this is followed by cleavage of the cell-protoplasm. Starting with the nucleus in the quiescent or *resting* condition, these changes may be briefly grouped under the three following stages (fig. 2):

1. *Anaphase*.—The nuclear network of chromatin filaments assumes the form of a twisted *skein* or *spirem*, and the nuclear membrane and nucleolus disappear. The convoluted skein of chromatin divides into a definite number of segments or *chromosomes*. The number of chromosomes varies widely in different animals, but is constant for all the somatic cells in an animal of any given species; in man the number is given by Flemming and Duesberg as twenty-four.† Coincidently with or preceding these changes, the centrosome divides, and the two resulting centrosomes are seen to be connected by a spindle of delicate achromatic fibres, the *achromatic spindle*. The centrosomes move away from each other—one towards either extremity of the nucleus—and the fibrils of the achromatic spindle are correspondingly lengthened. An imaginary line encircling the spindle midway between its extremities or *poles* is named the *equator*, and around this the chromosomes arrange themselves, forming what is known as the *equatorial plate*.

* Consult in this connexion *An Introduction to the Study of Cytology* by L. Doncaster, 1920.
† Dr. J. Duesberg, *Anat. Anz.*, Band xxviii. S. 475.

2. *Metaphase.*—Each chromosome splits longitudinally into two equal parts or *daughter chromosomes* which travel in opposite directions along the fibrils of the achromatic spindle towards the centrosomes, around which they group themselves; and thus each group contains the same number of chromosomes as was present in the equatorial plate.

FIG. 2.—A diagram showing the changes which occur in the centrosome and nucleus of a cell in the process of mitotic division, as seen in the epidermis of a larval salamander.



1 to 4 Anaphase; 5 and 6, Metaphase; 7 and 8, Kataphase. For further details see text.

3. *Kataphase.*—The daughter chromosomes become connected into a *skein* or *spirem*, and eventually form the network of chromatin which is characteristic of the resting nucleus. The nuclear membrane and nucleolus are also differentiated during this phase. The cell-protoplasm undergoes constriction around the equator of the achromatic spindle, where double rows of granules are also sometimes seen. The constriction deepens and the original cell is gradually divided.

The term *telophase* is sometimes applied to the concluding steps of the process of division, in which the daughter cells are finally separated and their nuclei and centrosomes assume the characteristics of the resting stage.

Homotypical and heterotypical mitosis.—In all somatic cells the process of mitosis conforms to the type described above, and is called *homotypical*. On its completion the nucleus of each daughter cell has as many chromosomes as were present in the nucleus of the mother cell.

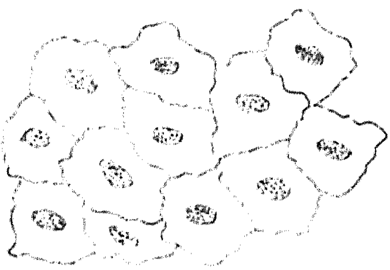
During the maturation of an oöcyte (p. 42) and also during the subdivision of a spermatocyte into spermatids (p. 44) two consecutive divisions occur, but the nucleus of each of the four cells resulting from these divisions has only half as many

chromosomes as were present in that of the oöcyte or spermatocyte. The reduction occurs during the first or *heterotypical* division. In this variety of mitosis the chromosomes arrange themselves in pairs, and each pair unites to form an elongated ring. The rings group themselves around the equator of the achromatic spindle, and each ring divides into two daughter chromosomes. One-half of the daughter chromosomes travel to one pole, and one-half to the other pole, of the spindle, to form two daughter nuclei: the cell then divides. The second division is homotypical.

EPITHELIUM

All the surfaces of the body—the external surface of the skin, the internal surfaces of the digestive, respiratory, and genito-urinary tracts, the closed serous cavities, the inner coats of the vessels, the acini and ducts of all secreting and excreting glands, the ventricles of the brain and the central canal of the medulla spinalis—are covered by one or more layers of cells, called *epithelium* or *epithelial cells*. These cells serve various purposes. Thus, in the skin, the main purpose served by the epithelium (here called the *epidermis*) is that of protection; as the surface is worn away by the agency of friction new cells are supplied, and thus the true skin and the vessels and nerves which it contains are defended from damage. The epithelial cells of the salivary glands, the pancreas, the gastric glands, and the glands of the small intestine prepare the digestive juices; those covering the intestinal villi are concerned with the absorption of the products of digestion; those lining the serous cavities provide a smooth, moist surface.

Fig. 3.—Simple pavement epithelium.

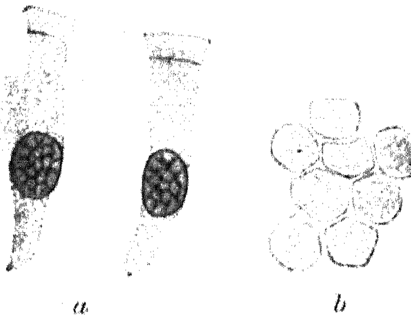


Epithelium consists of one or more layers of cells, usually supported on a basement-membrane, and united together by cement-substance, which is similar in chemical composition to the matrix or ground-substance of the connective tissues, and has the property of reducing nitrate of silver. Epithelia are naturally grouped into two classes according to whether there is a single layer of cells (*simple epithelium*), or more than one (*stratified epithelium* and *transitional epithelium*).

Simple epithelium.—The different varieties of simple epithelium are squamous or pavement, columnar, and ciliated.

Simple squamous or *pavement* epithelium (fig. 3) is composed of flat, nucleated cells of different shapes, usually polygonal, and varying in size. These cells fit together by their edges, like the tiles of a mosaic pavement. The nucleus is generally flattened, but may be spheroidal. The protoplasm of the cell may be fibrillated, the fibrils of adjacent cells being continuous across the intervening cement. This kind of epithelium forms the lining of the alveoli of the lungs. The so-called *endothelium*, which covers the serous membranes, and which lines the heart, blood-vessels and lymphatics, is also of the pavement type.

Fig. 4.—Columnar epithelial cells from the small intestine of the cat, stained with picrocarmine. × 600.

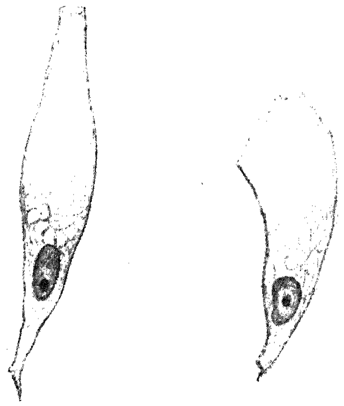


a, side view; *b*, cells seen from surface.

Columnar or *cylindrical* epithelium (fig. 4) consists of cylindrical or rod-shaped cells set together so as to form a complete layer, resembling, when viewed in profile, a palisade. The cells have a prismatic figure, from mutual pressure, and are set upright on the surface which supports them. The cell-protoplasm is always more or less reticulated; the nucleus is oval in shape and contains an intranuclear network; the centriole is double and lies near the surface of the cell. In the columnar epithelium of the intestinal villi, the free border of each cell shows a refractive

cap which exhibits well-defined vertical striations. Columnar epithelium lines nearly the whole gastro-intestinal tract and its glands, the greater part of the male urethra, the ductus deferens, the tubules and ducts of the prostate, the bulbo-urethral glands of Cowper, and the vestibular glands of Bartholin. In a modified form it also covers the ovary.

FIG. 5.—Goblet cells of a frog. × 500.



Goblet- or *chalice-cells* are modified columnar cells. Each appears to be formed by an alteration in shape of a columnar cell (ciliated or otherwise) consequent on the formation of granules, which consist of a substance called *mucinogen*, in the interior of the cell. This distends the upper part of the cell, while the nucleus is pressed down towards its deep part, until the cell bursts and the mucus is discharged on to the surface of the mucous membrane (fig. 5), the cell then assuming the shape of an open cup or chalice. A double centriole is found in the mucin-containing part of the goblet-cell. Cells of this kind are especially numerous in the mucous membrane of the stomach, and in the glands of the large intestine; they also occur in the epithelial covering of the villi of the small intestine and in that lining the respiratory tract (fig. 7).

The epithelium of glands is usually columnar, but in some the cells are cubical, in others they are polyhedral, in shape. The protoplasm shows a fine reticulum, which gives to the cells a granular appearance (fig. 6). Besides these protoplasmic 'granules,' gland-cells usually contain true granules which are the products of their own activity. These are in many cases zymogenic in nature, that is, they are, or contain, the precursors of enzymes or ferments.

FIG. 6.—Isolated liver-cells of a rabbit. × 500.

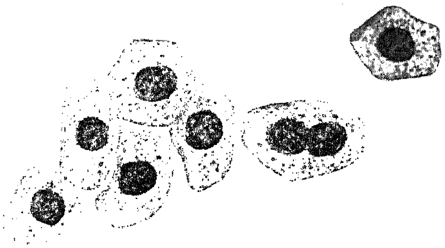


FIG. 7.—Ciliated epithelium from the trachea of a kitten. × 255.

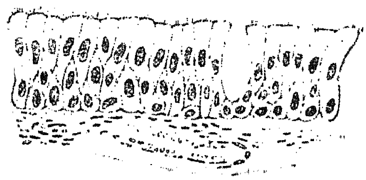
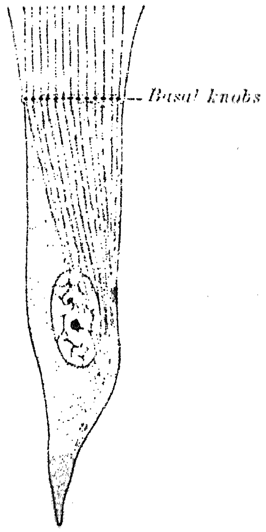


FIG. 8.—An isolated ciliated cell (semidiagrammatic).



Ciliated epithelium (fig. 7) is generally columnar in shape. It is distinguished by the presence of minute processes, resembling eyelashes (cilia), standing up from the free surface. The cilia (fig. 8), at their points of attachment to the free border of the cell, possess small nodular enlargements (*basal knobs* of Engelmann); from these knobs fine beaded filaments extend through the cell, and converge to a point near the fixed extremity. The basal knobs or particles have been supposed to be formed by division of the centriole. If the cells be examined during life or immediately on removal from the living body (for which in the human subject the removal of a nasal polypus offers a convenient opportunity) in a weak solution of salt, the cilia will be seen in lashing motion; and if the cells be separated, they will often be seen to be moved about in the field by this ciliary action.

Ciliated epithelium lines the respiratory tract from the nose downwards to the smallest ramifications of the bronchial tubes (except in the lower part of the pharynx and on the surfaces of the vocal folds); the tympanic cavity and auditory tube; the uterine tube and the cavity of the body of the uterus; the vasa efferentia, coni vasculosi and the first part of the ductus deferens; the ventricles of the brain and the central canal of the medulla spinalis.

FIG. 9.—Stratified epithelium from the œsophagus.

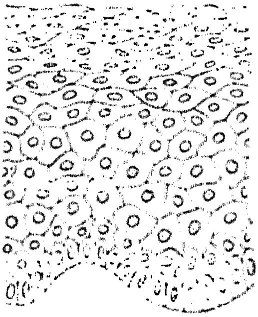
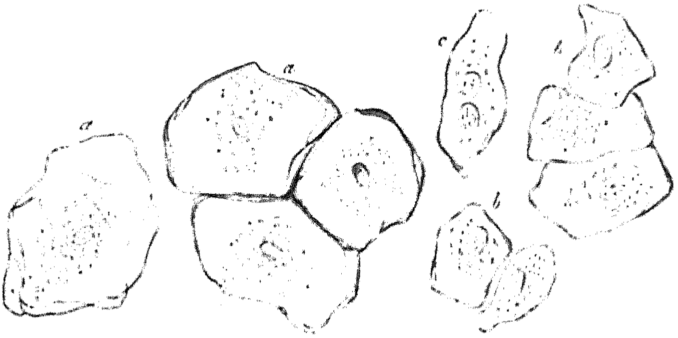


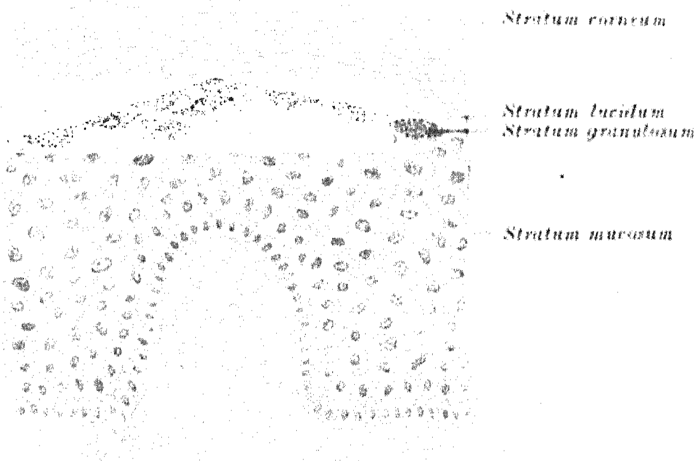
FIG. 10.—Epithelial cells from the oral cavity of man. × 350.



a. Superficial. *b.* From deeper layers. *c.* Cell with two nuclei.

Stratified epithelium (figs. 9 and 11) consists of several layers of cells. The cells vary greatly in shape; those of the deepest layer are for the most part columnar, and are placed vertically on the basement-membrane; above these are several layers of polyhedral cells, which as they approach the surface become more and more compressed, until the superficial ones are found to consist of flattened scales (fig. 10),

FIG. 11.—A section through the epidermis of the skin of the sole of the foot, stained with hæmatoxylin and van Gieson's stain. × 250.



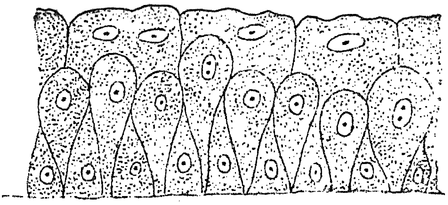
which overlap one another so as to present an imbricated appearance. The epithelium of the skin, or epidermis, is peculiar in that it shows four distinct layers. The deep layer consists of columnar and polyhedral cells as in stratified squamous epithelium generally (stratum mucosum). In the next layer, or stratum granulosum, the cells are fusiform in section, and contain granules of a substance called *eleidin*. The third layer, or stratum lucidum, consists of cells in which the eleidin has undergone a transformation into a substance called *keratohyalin*; and the cells of the

most superficial layer (stratum corneum) are completely converted into a horny material, known as *keratin* (fig. 11).

The cells of the deeper layers of stratified squamous epithelium are called *prickle-cells*; they are not closely joined together by cement-substance, but are separated from each other by intercellular channels, between which are protoplasmic bridges containing fine fibrils which connect the adjacent cells with each other. When a cell is isolated, it appears to be covered over with a number of short spines, in consequence of the bridges being broken through.

Stratified epithelium is found in the skin, in the conjunctiva, on the anterior surface of the cornea, and in the mucous membrane of the mouth, lower part of the pharynx, œsophagus, vagina and part of the cervix uteri.

FIG. 12.—Transitional epithelium.



Transitional epithelium occurs in the ureters and urinary bladder. Here the cells of the most superficial layer are large and flattened, with depressions on their under surfaces to fit on to the rounded ends of the cells of the second layer, which are pear-shaped, the apices touching the basement-membrane. Between the tapering points of the cells of the second layer is a third variety of cells of smaller size than those of the other two layers (fig. 12). In the distended condition of the bladder the superficial cells are more flattened, and the pear-shaped cells are shorter and broader than they are when the bladder is contracted.

THE CONNECTIVE TISSUES

The term **connective tissue** includes a number of tissues which have a passive function, that of binding together or supporting the functionally active structures: they differ considerably from each other in appearance, but present many points of relationship, and are, moreover, developed from the same layer of the embryo, the mesoderm. They are divided into three great groups: (1) the connective tissues proper, (2) cartilage, and (3) bone.

The circulating fluids (although functionally different) are regarded by some histologists as a form of connective tissue, and are dealt with in this section.

THE CONNECTIVE TISSUES PROPER

Several varieties of connective tissue are recognised: (1) Areolar tissue. (2) White fibrous tissue. (3) Yellow elastic tissue. (4) Mucoid tissue. (5) Retiform tissue. They are all composed of a homogeneous matrix, in which are imbedded cells and fibres—the latter of two kinds, white, and yellow or elastic. The distinction between the different varieties depends upon the relative preponderance of one or other kind of fibre, of cells, or of matrix.

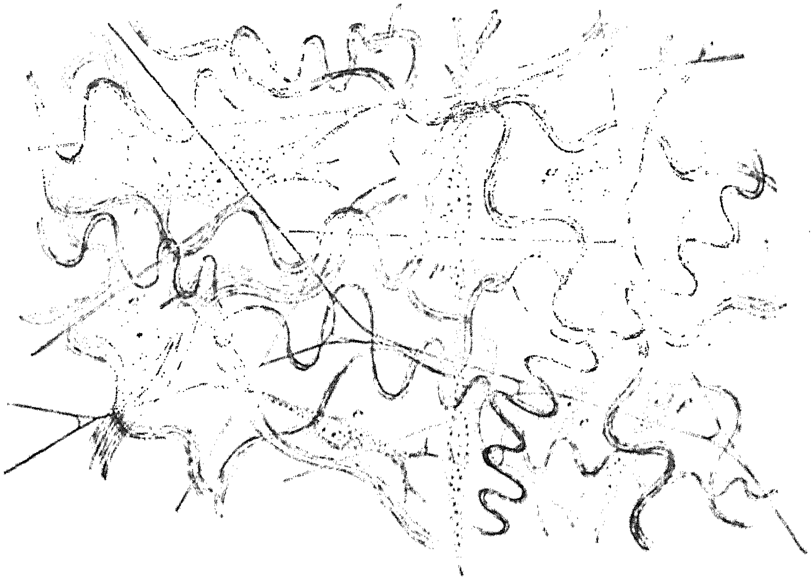
Areolar tissue (fig. 13) is so called because, when artificially distended with air or fluid, it exhibits intercommunicating areolæ or spaces. It is extensively distributed and its chief use is to bind parts together, though allowing, in virtue of its extensibility and elasticity, a considerable amount of movement to take place. It occurs as subcutaneous tissue, as the submucous coat in the digestive tract, and as subserous tissue. It is also found between muscles, vessels, and nerves, forming investing sheaths for them, and connecting them with surrounding structures. It is present in the interior of organs, binding together the lobes and lobules of the compound glands, the various coats of the hollow viscera, and the fibres of muscles and nerves.

When areolar tissue is stretched it is seen to be made up of soft elastic threads, resembling spun silk, and interlacing in all directions. A thin layer, examined under the microscope, shows fibres and cells, imbedded in a homogeneous ground-substance or *matrix*.

The fibres form an irregular meshwork, and are of two kinds, white and yellow. The *white fibres* are exceedingly fine; they are colourless, homogeneous and transparent, and are arranged parallel to each other in bundles, which have a wavy

course. The individual fibres do not branch, but small bundles of them may leave one large bundle to join another. The *yellow* or *elastic fibres* have well-defined out-

FIG. 13.—Subcutaneous tissue from a young rabbit. Highly magnified. (From Sir Edward Sharpey Schafer's Essentials of Histology.)



c, *c'*. Lamellar cell. *f*. Fibrillated cell. *g*. Plasma-cell. *p*. Clasmatocytes.

lines, and are usually somewhat larger than the white fibres, varying in diameter from 1μ to 6μ.* They are pale yellow in colour, homogeneous in appearance, run a

FIG. 14.—Areolar tissue of a rabbit, silvered. × 255. Ground-substance stained, cells unstained.

comparatively straight course, branch, and anastomose freely with each other. When they are broken across, the ends tend to curl up. They also differ from the white fibres in staining a dark red colour with orcein.

* A micromillimetre (μ) is $\frac{1}{1000}$ of a millimetre or $\frac{1}{25000}$ of an inch.

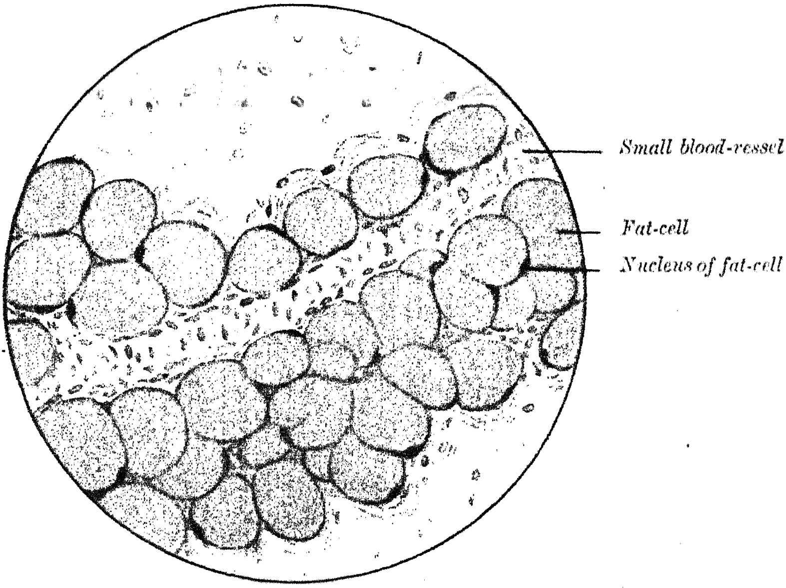
The cells of areolar tissue are of four principal kinds: (1) Flattened *lamellar cells*, may be either branched or unbranched. The branched lamellar cells are composed of clear protoplasm, with few granules, and contain oval nuclei; their processes may unite with those of neighbouring cells, so as to form a syncytium, as in the cornea. Occasionally a cell may be found which shows fibrillation of its protoplasm. Some observers believe such a condition to be a stage in the formation of the white fibres. The unbranched cells are joined edge to edge like the cells of an epithelium; the flattened cells lining the serous cavities are examples of this variety. (2) *Clasmatocytes* are large irregular cells characterised by the presence of granules or vacuoles in their protoplasm, and containing oval nuclei. (3) *Granule-cells* are ovoid or spheroidal in shape and contain basiphil granules. (4) *Plasma-cells* of Waldeyer are usually spheroidal in shape and distinguished by containing a vacuolated protoplasm; the vacuoles are filled with fluid, and the protoplasm between them is clear, with occasionally a few scattered basiphil granules.

In addition to these four types of cells, areolar tissue may contain *wandering cells*, i.e. leucocytes which have emigrated from the neighbouring vessels; in some instances, as in the chorioid coat of the eye, cells filled with granules of pigment (*pigment-cells*) are found.

The cells lie in spaces in the ground-substance between the bundles of fibres, and these spaces may be brought into view by treating the tissue with nitrate of silver and exposing it to the light; this will colour the ground-substance and leave the cell-spaces unstained (fig. 14).

Adipose tissue.—In almost all parts of the body areolar tissue contains a variable quantity of adipose tissue or fat. The principal situations where it is not found are the subcutaneous tissue of the eyelids, of the penis and scrotum, of the labia minora; within the cavity of the cranium; and in the lungs, except near their

FIG. 15.—Adipose tissue, from the omentum. Stained with Sudan III. and hæmatoxylin. ×350.

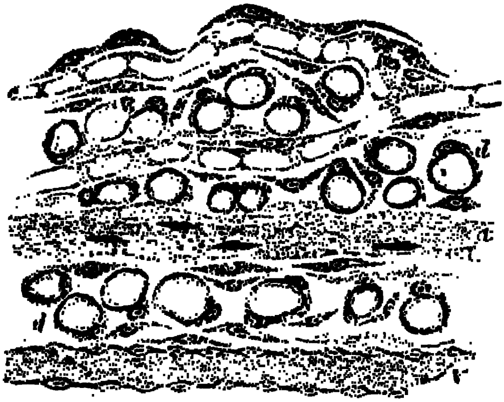


roots. The distribution of adipose tissue is not uniform; in some parts it is in great abundance, as in the subcutaneous tissue, especially of the abdomen, around the kidneys, and in the mesentery and omentum. Lastly, fat enters largely into the formation of the marrow of bones.

Adipose tissue consists of *fat-cells*, lodged in the meshes of areolar tissue. Fat-cells (fig. 15) vary in size, the average diameter being about 50μ; each consists of an exceedingly delicate protoplasmic membrane, filled with fatty substance, which is liquid during life, but solidifies after death. They are round or spherical where they are not subjected to pressure; otherwise they are more or less polygonal.

A nucleus is always present under the cell-membrane and can be demonstrated by staining with hæmatoxylin; in the natural condition it is so compressed by the contained oily matter as to be scarcely recognisable. The fat-cells are held together mainly by the network of capillary blood-vessels which is distributed to them.

Fig. 16.—Development of fat. (Klein and Noble Smith.)



a. Minute artery. v. Minute vein. c. Capillary blood-vessels in the course of formation; they are not yet completely hollowed out, there being still left in them protoplasmic septa. d. The ground-substance, containing numerous nucleated cells, some of which are more distinctly branched and flattened than others, and appear therefore more spindle-shaped.

Chemically the oily material is composed of olein, palmitin, and stearin, which are glycerol esters of fatty acids. Sometimes fat-crystals form in the cells after death. By boiling the tissue in ether or strong alcohol, the fat may be extracted from the cells, leaving them empty and shrunken.

Fat first appears in the human embryo about the fourteenth week. The fat-cells are formed by the transformation of connective tissue cells. Small droplets of oil are formed in the protoplasm, and these coalesce to produce a larger drop, which increases until it distends the cell, the remaining protoplasm and the nucleus being displaced towards the periphery (fig. 16).

White fibrous tissue is a true connecting structure, and serves three purposes in the animal economy. In the form of ligaments it binds bones together; in the form of tendons it connects muscles with bones or other structures; it constitutes investing or protecting membranes to various organs. Examples of such membranes are to be found in the muscular fasciæ or sheaths, the periosteum, and the perichondrium; the capsules of the various glands; the investing sheaths of the nerves (perineurium), and of various organs, as the penis and the eye.

Fig. 17.—White fibres. × 350.

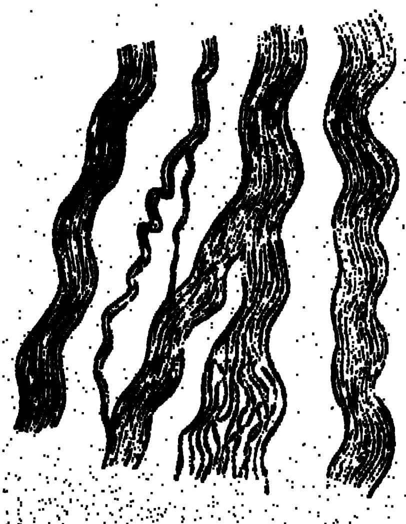
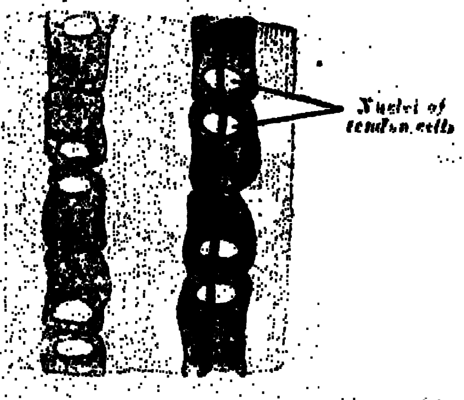


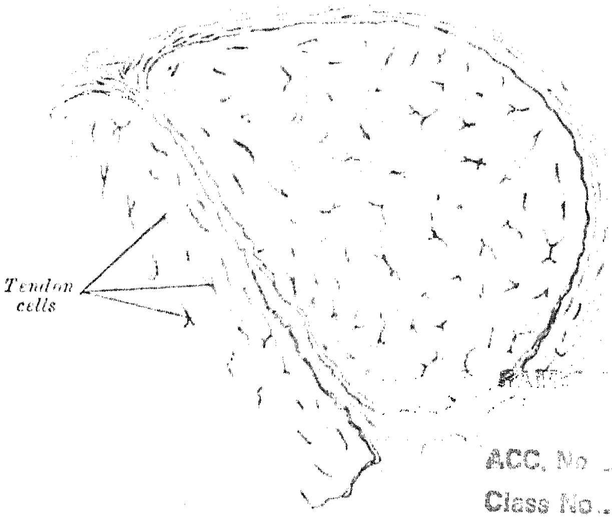
Fig. 18.—Tendon of a rat's tail, stained with gold chloride, showing chains of cells between the tendon-bundles. × 250.



In white fibrous tissue, as its name implies, the white fibres (fig. 17) predominate; the matrix is apparent only as a cement-substance, yellow elastic fibres are comparatively few, while the tissue-cells are arranged in a special manner. It presents to the naked eye a silvery white glistening appearance; it is devoid of elasticity, and has only the very slightest extensibility; it is exceedingly strong, so that, upon the application of any external violence, a bone with which it is

connected may fracture before the fibrous tissue gives way. In ligaments and tendons the bundles of fibres run parallel with each other; in membranes they intersect one another. The cells found in white fibrous tissue are often called 'tendon-cells.' They are situated on the surfaces of groups of fibres, and are arranged in rows, each cell being separated from its neighbours by a narrow line of cement-substance. The nucleus is generally situated at one end of the cell, the nucleus of the adjoining cell being in close proximity to it (fig. 18). The tendon-cells have

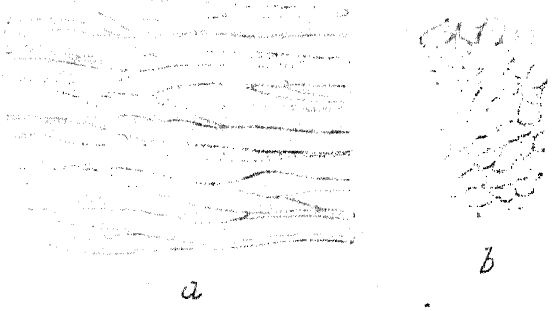
FIG. 19.—A transverse section through a tendon of a rat. × 120.



wing-like processes which pass between the bundles of fibres, giving a stellate appearance in transverse section (fig. 19). When viewed from the side, the cell with its wings is quadrangular, and there may be the appearance of a vertical line on the body of the cell owing to the projection of a wing towards the eye of the observer (fig. 18). Upon the addition of acetic acid, white fibrous tissue swells up into a glassy-looking indistinguishable mass. When boiled in water it is converted almost completely into gelatin, the white fibres being composed of *collagen*, which is regarded as the anhydride of gelatin.

Yellow elastic tissue.—In certain parts of the body a tissue is found which is of a yellowish colour, and possessed of great elasticity. It is capable of considerable extension, and when the extending force is withdrawn returns at once to its original condition. This is *yellow elastic tissue*; it may be regarded as a connective tissue in which the yellow elastic fibres have developed to the practical exclusion of the other elements. It is found in the ligamenta flava, in the vocal folds and conus elasticus of the larynx, in the mucous membrane of the trachea and bronchi, in the walls of the pulmonary air-vesicles, in the coats of the blood-vessels, especially the larger arteries, and to a very considerable extent in the hyothyreoid and stylohyoid ligaments. It is also found in the ligamentum nuchæ of the lower animals (fig. 20). Where the fibres are broad and large and the network close, the tissue presents the appearance of a membrane, with gaps or perforations corresponding with th

FIG. 20.—Ligamentum nuchæ of the ox, stained with picrocarmine. × 280.



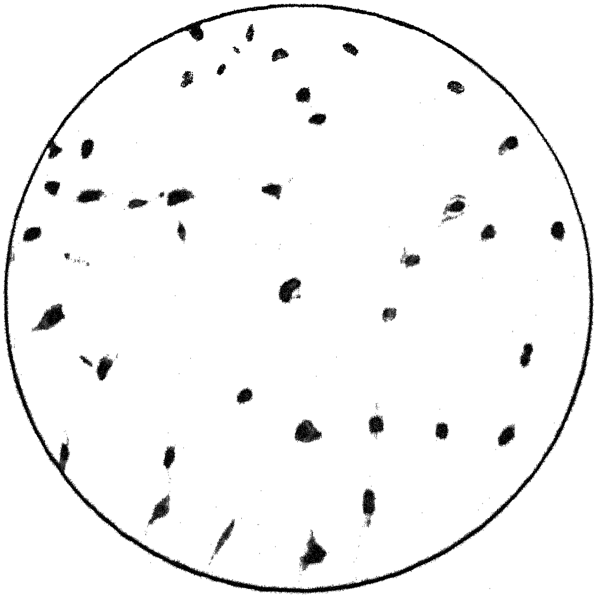
a. Longitudinal section. *b.* Transverse section.

intervening spaces. This is found in the inner coat of the arteries, and to it the name of *fenestrated membrane* has been given by Henle. Yellow elastic fibres remain unaltered by acetic acid; chemically they are composed of the sclero-protein known as *elastin*.

Mucoid tissue exists in the 'jelly of Wharton,' which forms the bulk of the umbilical cord, but is also found in the fœtus, chiefly as a stage in the development of connective tissue. It consists of a matrix, largely made up of mucin, in which are nucleated cells with branching and anastomosing processes (fig. 21). Few fibres are seen in typical mucoid tissue, though at birth the umbilical cord shows a considerable development of fibres. In the adult the vitreous body of the eye is a persistent form of mucoid tissue, in which the fibres and cells are very few in number.

Retiform or reticular tissue (fig. 22) is found extensively in many parts of the body, constituting the framework of some organs and entering into the construction of many mucous membranes. It is a variety of connective tissue, in which the

FIG. 21.—Mucoid tissue from the umbilical cord of a human embryo of four months, stained with hæmatoxylin and eosin. × 255.



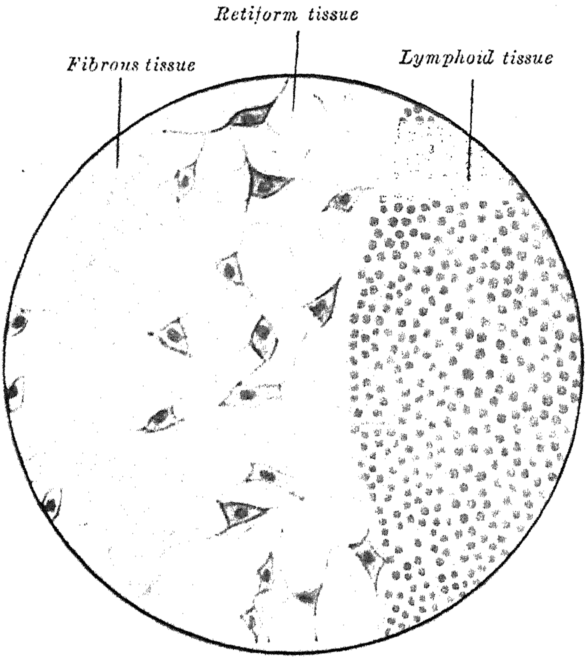
intercellular or ground-substance is, in a great measure, replaced by fluid. It is composed almost entirely of extremely fine bundles of white fibrous tissue, forming an intricate meshwork, and chemically it yields *gelatin* on boiling. The fibres are covered and concealed in places by flattened branched connective tissue cells. In many situations the interstices of the network are filled with rounded lymph-corpuscles, and the tissue is then termed **lymphoid tissue**.

Basement-membranes consist of thin sheets of modified connective tissue, and are found underlying layers of epithelial cells, for example, in mucous membranes and secreting glands. They may be formed of cells or of condensed ground-substance. In the former case, flattened cells, which are modified connective tissue corpuscles, are united by their edges by means of cement-substance, which can be demonstrated by staining with silver nitrate; if the cells are unbranched, the membrane is continuous; if they are branched, the processes are united, and the membrane is fenestrated. The basement-membrane underlying the epithelium on the anterior surface of the cornea is composed of ground-substance.

Vessels and nerves of connective tissue.—The *blood-vessels* of connective tissue are very few—that is to say, few are supplied to the tissue itself, although many carrying blood to other structures may permeate one of its forms, the areolar tissue. In white fibrous tissue the blood-vessels usually run parallel to and between the longitudinal bundles, sending communicating branches across the bundles; in some forms, as in the periosteum and dura mater, they are fairly numerous. In

yellow elastic tissue, the blood-vessels also run between the fibres. *Lymphatic vessels* are very numerous in most forms of connective tissue, especially in the areolar tissue beneath the skin and the mucous and serous surfaces. They are also found in abundance in the sheaths of tendons, as well as in the tendons themselves.

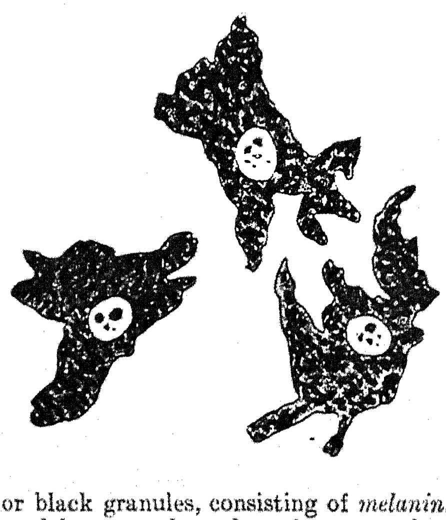
FIG. 22.—Retiform and lymphoid tissue from a lymph-gland, stained with picrocarmine. × 255.



Nerves are found in white fibrous tissue, where they end in a special manner; but it is doubtful whether any nerves end in areolar tissue; at all events, they have not yet been demonstrated, and the tissue is possessed of very little sensibility.

Pigment.—Pigment is found in various parts of the body; most frequently in epithelial cells and in the cells of connective tissue. Pigmented *epithelial cells* form the external layer of the retina, and are present on the posterior surface of the iris, in the olfactory region of the nose, in the membranous labyrinth of the ear, in the deeper layers of the cuticle, and in the hairs. Pigment is abundantly present in the skin of the coloured races, but in the skin of white races it is well-marked only in the areolæ round the mammary papillæ and in irregular coloured patches. Pigmented *connective tissue-cells* are frequently met with in the lower vertebrates. In man they are found in the chorioid coat of the eye (fig. 23), and in the iris of all but the light blue eyes and the albino. The cells are usually large and branched, and are filled with brown or black granules, consisting of *melanin.* In the retina the processes of the cells extend between the rods and cones; when the eye is exposed to light the pigment-granules extend into these processes, and under the influence of darkness they are withdrawn into the body of the cell.

FIG. 23.—Pigment-cells from the chorioid coat of the eyeball.

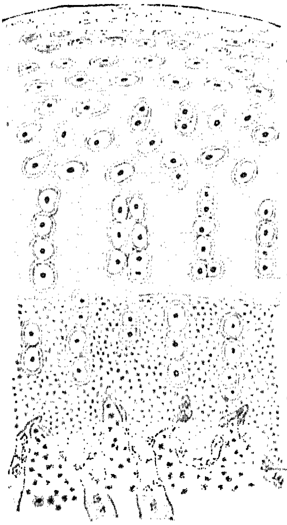


GRAY'S ANATOMY

Hyaline cartilage has a pearly bluish colour and consists of a gristly mass of a firm consistence, but of considerable elasticity. Except where it coats the articular ends of bones, it is covered by a fibrous membrane, the *perichondrium*, from the vessels of which it imbibes its nutritive fluids, being itself destitute of blood-vessels. It contains no nerves. If a thin slice be examined under the microscope, it is seen to consist of cells of a rounded or bluntly angular form, lying in spaces in a granular or almost homogeneous matrix (fig. 24). The cells are frequently arranged in groups of two or more, and, when this is so, they have generally straight outlines where they are in contact with each other, but are rounded in the rest of their circumference. They consist of clear translucent protoplasm in which fine interlacing filaments and minute granules are sometimes present; imbedded in the protoplasm are one or two round nuclei, having the usual intranuclear network.

The matrix is transparent and apparently without structure, or else presents a dimly granular appearance, like ground glass. The portion immediately surrounding each cell-space is often well-defined, and is further characterised by its affinity for basic dyes. It is known as the *capsule* of the space. The matrix of hyaline cartilage, and especially that of the articular variety, can be broken up into fine fibrils after prolonged maceration. These fibrils are probably of the same nature, chemically, as the white fibres of connective tissue. It is believed by some histologists that the matrix is permeated by a number of fine channels, which connect the cell-spaces with each other and with the lymphatics of the perichondrium, and that in this way nutrient fluid obtains access to the cartilage-cells.

FIG. 25.—A vertical section through articular cartilage.



Articular cartilage, costal cartilage, and temporary cartilage are all of the hyaline variety, but they present differences in the size, shape, and arrangement of their cells.

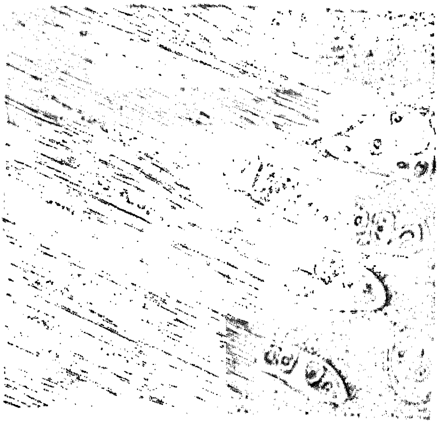
Articular cartilage (fig. 25) shows no tendency to ossification: its matrix is finely granular, and its cells are flattened and disposed parallel to the surface in the superficial part of the cartilage, while nearer to the bone they are oval and are arranged in vertical rows. It has a tendency to split in a vertical direction. Its free surface is not covered by perichondrium, but the synovial stratum of the articular capsule can be traced over a small part of its circumference, and here the cartilage-cells are more or less branched and pass insensibly into the branched connective tissue-cells of the synovial stratum. It forms a thin layer upon the joint-surfaces of the bones, and its elasticity enables it to break the force of concussions, while its smoothness gives ease and freedom of movement. It varies in thickness according to the shape of the articular surface on which it lies; where this is convex the cartilage is thickest at the centre, the reverse being the case on concave articular surfaces. It appears to derive its nutriment partly from the vessels of the synovial stratum of the joint-capsule and partly from those of the bone upon which it is implanted. The minute vessels of the spongy bone dilate and form arches as they approach the articular lamella, and then return into the substance of the bone.

In **costal cartilage** the cells and nuclei are large, and the matrix, which is usually homogeneous and transparent, has a tendency to fibrous striation, especially in old age (fig. 26). In the thickest parts of the costal cartilages a few large vascular channels may be detected. This appears, at first sight, to be an exception to the statement that cartilage is non-vascular, but is not so really, for the vessels give no branches to the cartilage itself, and the channels may rather be looked upon as involutions of the perichondrium. The xiphoid process of the sternum and the

cartilages of the nose, larynx, and trachea (except the epiglottis and corniculate cartilages of the larynx, which are composed of elastic fibrocartilage) resemble the costal cartilages in microscopical characteristics. The arytænoid cartilage of the larynx shows a transition from hyaline cartilage at its base to elastic cartilage at the apex.

The hyaline cartilages, especially in adult and advanced life, are prone to calcify—that is to say, their matrix becomes permeated by calcium salts. Calcification occurs frequently in the costal cartilages, and in the cartilages of the trachea, and may be succeeded by ossification.

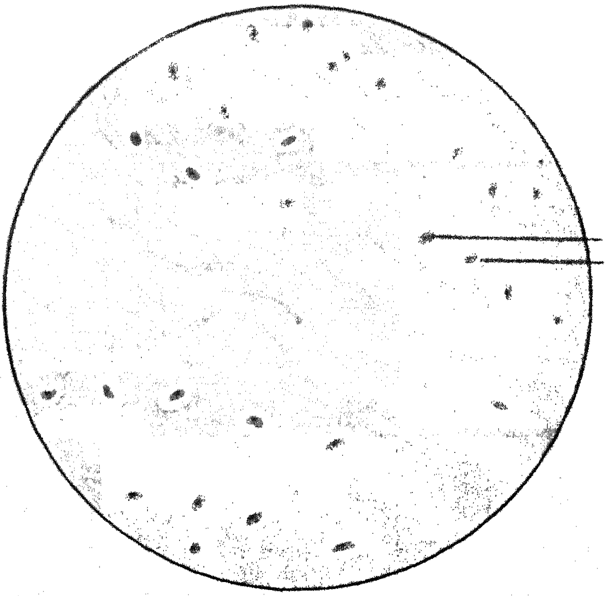
Fig. 26.—Costal cartilage from a man seventy-six years of age, showing the development of fibrous structure in the matrix. In several portions of the specimen two or three generations of cells are seen enclosed in a parent cell-wall. Highly magnified.



White fibrocartilage consists of fibrous connective tissue arranged in bundles, with cartilage-cells between the bundles; the cells are roughly ovoid in shape, and are surrounded by concentrically striated areas of cartilage matrix (fig. 27). The white fibrocartilages admit of arrangement into four groups—interarticular, connecting, circumferential, and stratiform.

1. The *interarticular fibrocartilages* (*menisci*) are flattened fibrocartilaginous plates, of a round, oval, triangular, or sickle-like form, interposed between the articular cartilages of certain joints; the synovial stratum of the articular capsule covers their free surfaces. They are found in the temporomandibular, sternoclavicular, acromioclavicular, wrist- and knee-joints. Their uses are to obliterate the intervals between opposed surfaces in their various motions; to increase the depths of the articular surfaces

Fig. 27.—White fibrocartilage from the intervertebral fibrocartilage of a sheep, stained with borax-carmine. × 300.



and give ease to the gliding movements; they also increase the varieties of movement in a joint.

2. The *connecting fibrocartilages* are interposed between the bony surfaces of

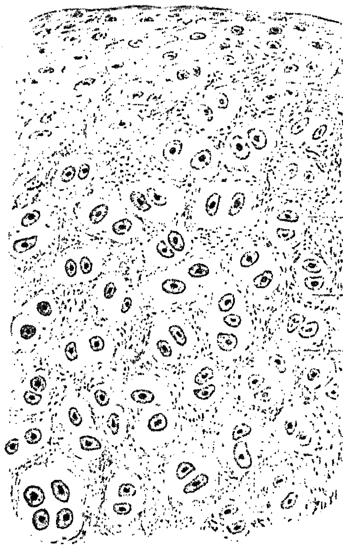
those joints which admit of only slight mobility, as between the bodies of the vertebræ. They form discs which are closely adherent to the opposed surfaces. Each disc is composed of concentric layers of fibrous tissue, with cartilaginous laminæ interposed, the former tissue predominating towards the circumference, the latter towards the centre.

3. The *circumferential fibrocartilages* consist of rims of fibrocartilage, which surround the margins of some of the articular cavities, e.g. the glenoidal labrum of the hip-joint and that of the shoulder-joint; they serve to deepen the articular cavities and to protect their edges.

4. The *stratiform fibrocartilages* form thin coatings to osseous grooves through which the tendons of certain muscles glide.

Small masses of fibrocartilage are also developed in the tendons of some muscles, where they glide over bones, as in the tendons of the Peronæus longus and Tibialis posterior.

FIG. 28.—Yellow or elastic fibrocartilage from the epiglottis of a cat. × 250.



Yellow or elastic fibrocartilage is found in the ears, the corniculate cartilages of the larynx, and the epiglottis. It consists of cartilage-cells and a matrix, the latter being pervaded by a network of yellow elastic fibres, branching and anastomosing in all directions, except immediately around the cells, where there is a variable amount of hyaline substance (fig. 28). The fibres resemble those of yellow elastic tissue, not only in appearance, and in being unaffected by acetic acid, but also in their affinity for orcein; according to Rollett their continuity with the elastic fibres of the neighbouring tissue is demonstrable.

The distinguishing feature of cartilage, chemically, is that it yields on boiling a substance called *chondrin*, a mixture of gelatin with mucinoid substances, chief among which is a compound termed *chondromucoid*.

BONE

Structure and physical properties.—Bone is one of the hardest structures of the animal body; it possesses also a certain degree of toughness and elasticity. Its colour, in a fresh state, is pinkish white externally, and deep red within. In section it is seen to be composed of two kinds of tissue, one of which is dense in texture, like ivory, and is termed *substantia compacta*; the other consists of slender fibres and lamellæ, which join to form a reticular structure; this is called *substantia spongiosa* or, from its resemblance to lattice work, *cancellous tissue*. The compact substance is always placed on the exterior of the bone, the spongy in the interior. The relative quantities of these vary in different bones and in different parts of the same bone, according as strength or lightness is requisite. Close examination of the compact substance shows it to be extremely porous, so that the difference between it and the spongy substance depends merely upon the relative amount of solid matter and the size and number of spaces in each; in the compact substance the spaces are small and the solid matter abundant, while in the spongy substance the spaces are large and the solid matter small in quantity.

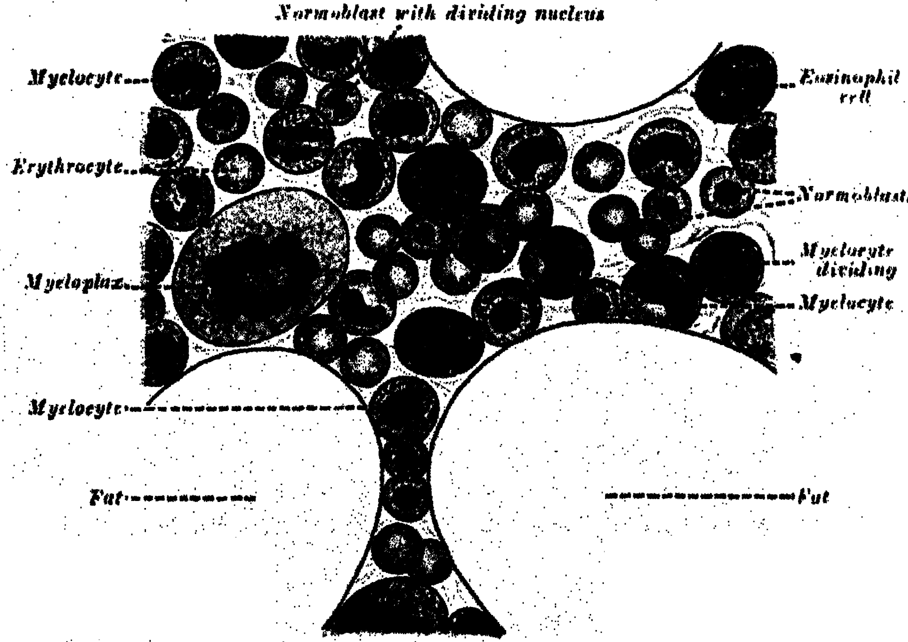
During life, bone is permeated by vessels, and enclosed, except where it is coated with articular cartilage, in a fibrous membrane, the *periosteum*, by means of which many of these vessels reach the bone. If the periosteum be stripped from the surface of the living bone, small bleeding points are seen which mark the entrance of the periosteal vessels; and on section every part of the bone exudes blood from

the minute vessels which ramify in it. In the interior of the long bones of the limbs is a cylindrical cavity (*cavum medullare*) filled with *medulla ossium* or *marrow*, and lined with a membrane composed of highly vascular areolar tissue, called the *medullary membrane* or *internal periosteum*.

The **periosteum** adheres to the surfaces of the bones in nearly every part, but not to the cartilage covering their articular surfaces. When strong tendons or ligaments are attached to a bone, the periosteum is incorporated with them. It consists of two layers closely united together, the outer formed chiefly of white fibrous tissue, containing occasionally a few fat-cells; the inner, of elastic fibres of the finer kind, forming dense membranous networks, which can be again separated into several layers. In young bones the periosteum is thick and very vascular, and is intimately connected at either end of the bone with the epiphysial cartilage, but less closely with the body of the bone, from which it is separated by a layer of soft tissue, containing a number of granular corpuscles or 'osteoblasts,' by which ossification proceeds on the exterior of the young bone. Later in life the periosteum is thinner and less vascular, and the osteoblasts are represented by a single layer of flattened cells on its deep surface. The periosteum serves as a nidus for the ramification of the vessels previous to their distribution in the bone; hence the liability of bone to exfoliation or necrosis when denuded of this membrane by injury or disease. Fine nerves and lymphatics, which generally accompany the arteries, may also be demonstrated in the periosteum.

The **medulla ossium or marrow** not only fills up the cylindrical cavities in the bodies of the long bones, but also occupies the spaces of the cancellous tissue and extends into the larger Haversian canals. It differs in composition in different bones. In the bodies of the long bones the marrow is of a *yellow* colour (*medulla ossium flava*), and consists of a basis of connective tissue supporting numerous blood-vessels and cells, most of which are fat-cells, but some are 'marrow-cells,'

FIG. 29.—Human bone-marrow. Highly magnified.



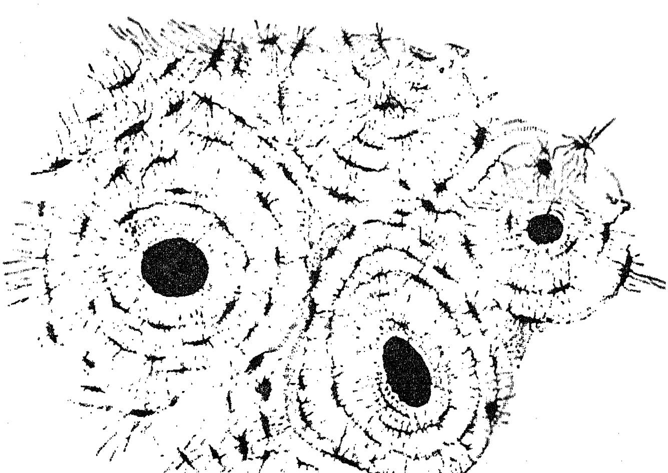
such as occur in the red marrow. In the flat and short bones, in the articular ends of the long bones, in the bodies of the vertebræ, in the cranial diploë, and in the sternum and ribs, the marrow is of a *red* colour (*medulla ossium rubra*).* Red marrow consists of a small quantity of connective tissue, blood-vessels, and numerous cells (fig. 29), a few of which are fat-cells but the great majority are spherical,

* Alfred Pinney (*Lancet*, Sept. 9th, 1922, p. 572) has investigated the naked-eye anatomy of the bone marrow in 1700 post-mortem cases, and concludes that all the bones, except those of the cranium, contain red marrow until puberty.

nucleated cells, termed *myelocytes* or *marrow-cells*. The myelocytes resemble the leucocytes of the blood, and like them are amœboid; they contain granules, either oxyphil, basiphil or neutrophil in reaction. A number of eosinophil cells and a few basiphil cells are also present. Amongst the myelocytes may be seen smaller nucleated cells, of a yellowish colour; these are the *erythroblasts* or *normoblasts* from which the red corpuscles of the blood are derived by the disappearance of the nuclei. Giant-cells (*myeloplaxes* or *megakaryocytes*) similar to the osteoclasts described in connexion with the development of bone are also found in red marrow. In post-natal life the red marrow is the chief seat of the formation of the corpuscles of the blood.

Vessels and nerves of bone.—The *blood-vessels* of bone are very numerous. Those of the compact substance are derived from a close network of vessels in the periosteum. Vessels pass from this network into the minute orifices in the compact substance, and run in the Haversian canals which traverse it. The spongy substance is supplied in a similar way by larger vessels, which perforate the outer compact substance, and are distributed to the cavities of the spongy portion of the bone. In the long bones, numerous apertures may be seen at the ends near the articular surfaces; some of these give passage to arteries, but the greater number transmit veins from the spongy substance. The marrow of a long bone is supplied by an artery which enters the bone at the nutrient foramen (*foramen nutricium*). The *nutrient* artery, usually accompanied by one or two veins, sends branches upwards and downwards, which ramify in the medullary membrane, and give twigs to the adjoining Haversian canals. The ramifications of this vessel anastomose with the arteries of the spongy and compact substances. In most of the flat, and in many of the short, bones there are one or more large apertures for the transmission of nutrient vessels. Veins emerge from the long bones as follows:—(1) one or two accompany the nutrient artery; (2) numerous large and small veins emerge near the articular extremities; (3) many small veins pass out of the compact substance. In the flat cranial bones the veins are large and run in tortuous canals in the diploic tissue, the walls of the canals being formed by thin lamellæ of bone, perforated here and there for the passage of branches from the adjacent diploë. The same condition is found in all spongy substance, the veins being enclosed and supported by osseous material, and having exceedingly thin coats. When a bone is divided, the vessels remain open, and do not contract in the canals in which they are contained. *Lymphatic vessels*, which communicate with those in the periosteum, are found in the Haversian canals. *Nerves* are distributed freely to the periosteum, and accompany the nutrient arteries into the interior of the bone. They are said to be most numerous in the articular extremities of the long bones, in the vertebræ, and in the larger flat bones.

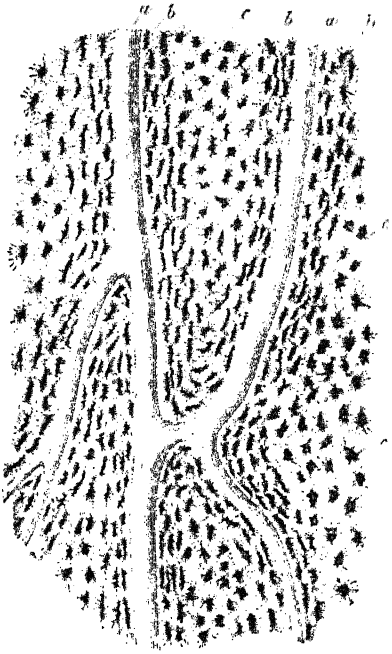
FIG. 30.—A transverse section through the compact substance of bone. Magnified. (Sharpey.) (From Quain's Elements of Anatomy.)



Minute anatomy.—If a thin transverse section of dense bone be examined with a low power of the microscope it will be seen to be mapped out into a number of

circular districts, each consisting of a central hole surrounded by a number of concentric rings. These districts are termed *Haversian systems*; the central hole is a *Haversian canal*, and the rings are *lamellæ* of bony tissue arranged concentrically around the central canal. Between these lamellæ are a number of small spaces termed *lacunæ*, which are connected with each other and with the central Haversian canal by many fine radiating channels called *canaliculi*. Filling in the irregular intervals between these circular districts are *interstitial* lamellæ, with their lacunæ and canaliculi, running in various directions, but more or less parallel with the surface (fig. 30). Again, other lamellæ are found on the surface of the bone completely encircling it; they are termed *circumferential* or *primary* lamellæ, to distinguish them from those surrounding the Haversian canals, which are termed *secondary* lamellæ.

Fig. 31.—A longitudinal section of the body of the femur. × 100.

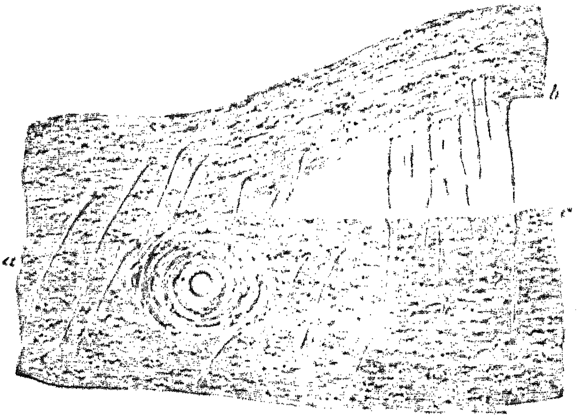


a. Haversian canals. b. Lacunæ seen from the side. c. Others seen from the surface in lamellæ which are cut horizontally.

In a longitudinal section it will be seen that the Haversian canals run parallel with the long axis of the bone but branch and communicate at short intervals (fig. 31). They vary considerably in size, but their average diameter is about 0·05 mm. The canals near the medullary cavity are larger than those near the surface of the bone. Each canal usually contains a minute artery and vein, a small quantity of delicate connective tissue, and some nerve-filaments; in the larger ones there are also lymphatic vessels, and cells with branching processes.

The *lamellæ* are thin plates of bony tissue. They may be stripped off as thin films from a piece of bone which has been macerated in dilute mineral acid. If one of these films be examined with a high power of the microscope, it will be found

Fig. 32.—The perforating fibres of a human parietal bone, decalcified. (H. Müller.) (From Quain's Elements of Anatomy, vol. ii. pt. i., Microscopic Anatomy.)



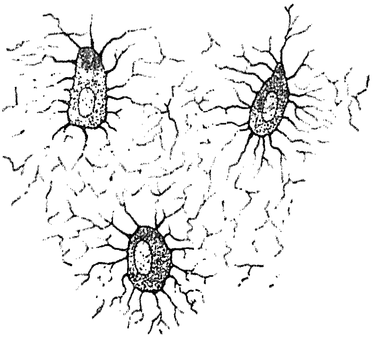
a. Perforating fibres *in situ*; b. Fibres drawn out of their sockets; c. Sockets.

to be composed of fine fibres identical with the white fibres of connective tissue. The matrix between the fibres is impregnated with lime-salts which the acid dissolves. The fibres are arranged in bundles, and fibres leave the bundles of one lamella to join those of adjacent lamellæ. Moreover, the fibres of one lamella usually form an acute

angle with those of the contiguous layer; in the Haversian systems, however, the fibres of adjacent lamellæ run at right angles to each other. In many places the various lamellæ are held together by tapering fibres, which run obliquely through them, pinning or bolting them together; these fibres were first described by Sharpey, and were named by him *perforating fibres* (fig. 32.)

The *lacunæ* are oblong spaces situated between the lamellæ, and each lacuna is occupied during life by a branched *bone-cell* (fig. 33), the processes from which extend into the canaliculi.

Fig. 33.—Nucleated bone-cells and their processes, contained in the bone-lacunæ and their canaliculi respectively. From a section through the vertebra of an adult mouse. (Klein and Noble Smith.)



The *canaliculi* are minute channels, crossing the lamellæ and connecting the lacunæ of a Haversian system with one another, and with the Haversian canal. The canaliculi at the periphery of a Haversian system do not as a rule communicate with those of neighbouring systems, but form loops and return to their own lacunæ. Thus every part of a Haversian system is supplied with nutrient fluids derived from the vessels in the Haversian canal and distributed through the canaliculi and lacunæ.

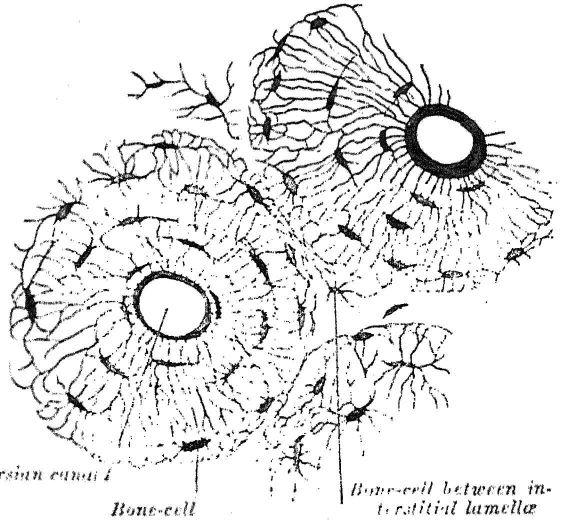
The *bone-cells* occupy, but do not fill, the lacunæ. They are flattened nucleated branched cells, homologous with the lamellar cells of connective tissue; their branches pass into the canaliculi.

In thin plates of bone Haversian canals are absent.

Chemical composition.—Bone consists of animal or organic, and mineral or inorganic, substances intimately combined.

The animal substance forms about 33 per cent. of the total weight,* and may be obtained by immersing a bone for a considerable time in dilute mineral acid which will dissolve the mineral matter. The bone retains its shape, but is now

Fig. 34.—A transverse section through a portion of the body of a human fibula, decalcified. × 250.



perfectly flexible, so that a long bone (one of the ribs, for example) can easily be tied in a knot. In a transverse section of such a softened bone (fig. 34), the arrangement of the Haversian canals, lamellæ, lacunæ, and canaliculi can be recognised.

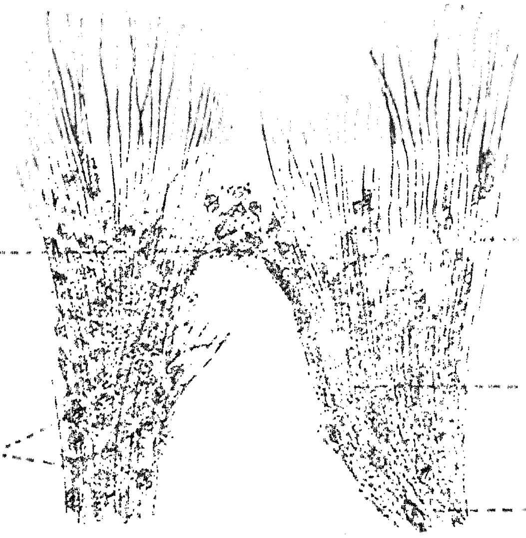
* H. E. Radasch (*Proceedings of the American Association of Anatomists, Anatomical Record*, vol. 21) states that in 'green' bone the organic substance averages 40·75 per cent.

The mineral substance may be obtained by calcination, which destroys the animal matter. The bone retains its original form, but is white and brittle, has lost about one-third of its original weight, and crumbles under the slightest force. The mineral substance, composed chiefly of calcium phosphate, forms about 66·7 per cent. of the weight of the bone; it confers on bone its hardness and rigidity, while the animal matter (*ossein*) determines its resiliency and tenacity.

Ossification.—Some bones, such as those of the roof and sides of the skull, are preceded by membrane, but most bones are preceded by rods or masses of cartilage. Hence two kinds of ossification are described: the *intramembranous* and the *intracartilaginous*.

Intramembranous ossification.—The membrane which occupies the place of the future bone is of the nature of connective tissue, and ultimately forms the

Fig. 35.—A part of the growing edge of the developing parietal bone of a fœtal cat. (From Quain's Elements of Anatomy: Sir Edward Sharpey Schafer.)



periosteum; it is composed of fibres and granular cells in a matrix richly supplied with blood-vessels. The peripheral portion is more fibrous, while in the central portion the cells or *osteoblasts* predominate. At the outset of the process of bone formation a little network of fibres radiates from the centre of ossification. These rays consist at their growing points of a network of fine clear fibres and granular corpuscles with an intervening ground-substance (fig. 35). The fibres are termed *osteogenetic* fibres, and differ little from those of white fibrous tissue. The membrane assumes a dark and granular appearance from the deposition of calcareous granules in the matrix between the fibres, and in the calcified material some of the granular cells or osteoblasts are enclosed. By the fusion of the calcareous granules the tissue again assumes a more transparent appearance, but the fibres are no longer so distinctly seen. The osteoblasts form the bone-cells of the future bone, the spaces in which they are enclosed constituting the lacunæ. As this process advances, a network of bone is formed, the meshes of which contain the blood-vessels and a delicate connective tissue crowded with osteoblasts. The bony trabeculæ thicken by the addition of fresh layers formed by the osteoblasts on their surface, and the meshes are correspondingly encroached upon. Subsequently the bone increases in thickness by the deposition of successive layers under the periosteum and round the larger vascular channels which become the Haversian canals.

Intracartilaginous ossification.—Most of the bones are ossified in cartilage. Each long bone, for example, is represented in early fœtal life by a rod of hyaline cartilage. Ossification commences in the centre of the rod and proceeds towards the ends, which for some time remain cartilaginous. Subsequently ossification begins at one or more centres in either end, and gradually extends, but a superficial layer of cartilage persists, constituting the articular cartilage. The ossified extremities do not, however, fuse with the body of the bone until growth has ceased;

between the body and either end a plate of cartilage termed the *epiphysial cartilage* persists throughout the period of growth.

At the *centre of ossification*, or point where the ossifying process begins, the cartilage-cells multiply and enlarge and become arranged in rows radiating from the centre (fig. 36). The matrix in which the cells are imbedded increases in quantity, so that the latter are further separated from each other.

A deposit of calcareous material now takes place in this matrix, so that it presents a granular and opaque appearance. The cartilage-cells are enclosed in oblong cavities, the walls of which are formed of calcified matrix which cuts off all nutrition from the cells; the cells, in consequence, atrophy, leaving spaces called the *primary areolæ*.

While this process is going on in the centre of the bar of cartilage, certain changes are taking place on its surface. This is covered by a very vascular membrane, the *perichondrium*, formed of connective tissue similar to that already described as constituting the basis of membrane-bone; on the inner surface of this—that is to say, on the surface in contact with the cartilage—are gathered the formative cells, the *osteoblasts*. By the agency of these cells a thin layer of bony tissue is laid down, between the perichondrium and the cartilage, by the *intramembranous* mode of ossification just described. There are then, in this first stage, two processes going on simultaneously: in the centre of the cartilage the formation of a number of oblong spaces, bounded by calcified matrix and containing the withered cartilage-cells, and on the surface of the cartilage the formation of a layer of true membrane-bone. The second stage consists in the prolongation into the cartilage of processes of the deeper or osteogenetic layer of the perichondrium (now periosteum) (fig. 36, *ir*). The processes consist of blood-vessels and cells—*osteoblasts*, or bone-formers, and *osteoclasts*, or bone-destroyers. The latter are large, multinucleated protoplasmic masses, and they excavate passages through the new-formed bony layer by absorption, and pass through it into the calcified matrix (fig. 38). Wherever these processes of the osteogenetic layer come in contact with the calcified walls of the primary areolæ they absorb them, and thus cause a fusion of the original cavities and the formation of larger spaces, which are termed the *secondary areolæ* or *medullary spaces*. These secondary spaces are filled with embryonic marrow, consisting of osteoblasts and vessels, derived, in the manner described above, from the osteogenetic layer of the periosteum (fig. 37).

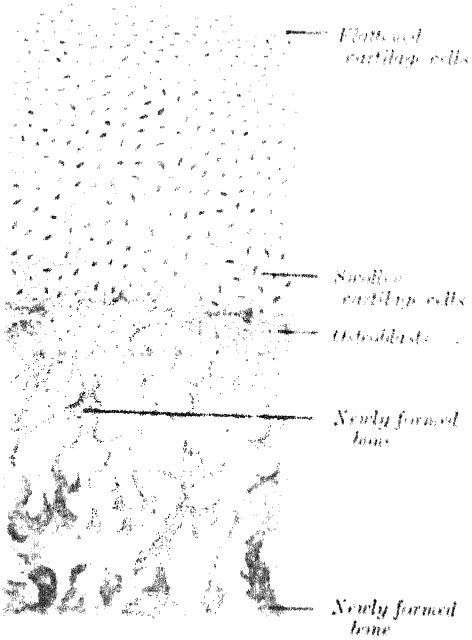
Fig. 36.—A section through a fœtal bone of a cat. (From Quain's Elements of Anatomy: Sir Edward Sharpey Schafer.)

im. Subperiosteal bony deposit. *ir.* Irruption of the subperiosteal tissue. *o.* Layer of osteoblasts. *p.* Fibrous layer of the periosteum.

The walls of the secondary areolæ increase in thickness by the deposition of layers of bone on their surface. This process takes place in the following manner. Some of the osteoblasts of the embryonic marrow, after undergoing rapid division, arrange themselves as a layer on the surface of the wall of the space (fig. 37). This layer of osteoblasts forms a bony stratum, which gradually covers the wall of the space and in which some of the osteoblasts are included as bone-cells. The next

stage in the process consists in the removal of these primary bone-spicules by the osteoclasts, one of which may be seen lying in a Howship's foveola at the free end of each spicule (fig. 38). The removal of the primary spicules goes on *pari passu* with the formation of permanent bone by the periosteum, and in this way the medullary cavity of the bone is formed.

Fig. 37.—A part of a longitudinal section through the developing femur of a human fœtus. Stained with borax carmine. × 100.



This series of changes proceeds gradually towards the ends of the bone, so that all the changes described above may be seen in different parts, from the true bone at the centre of the body to the hyaline cartilage at the extremities.

While the ossification of the cartilaginous body is extending towards the articular ends, the epiphysial cartilage immediately in advance of the osseous tissue continues to grow until the length of the adult bone is reached.

The articular end remains for some time cartilaginous, and then one or more secondary bony centres appear, and initiate in it the process of ossification; but the extremity remains separated from the body of the bone by the epiphysial cartilage for a definite time. This cartilage ultimately ossifies, and the bone assumes its completed form and shape. The same remark applies to such processes of bone as are ossified from separate epiphyses, e.g. the trochanters of the femur. Bones increase in length by ossification continuing to extend into the epiphysial cartilage, which goes on growing in advance of the ossifying process. They increase in circumference by

Fig. 38.—Osteoblasts and osteoclasts in the developing femur of a kitten. × 350.

deposition of new bone, from the deep layer of the periosteum, on their external surfaces, and at the same time an absorption takes place from within, by which the medullary cavities are increased.

The permanent bone formed by the periosteum when first laid down is spongy in structure. Later the osteoblasts contained in its spaces form the concentric layers characteristic of the Haversian systems, and are included as bone-cells.

The number of ossific centres varies in different bones. Most of the short bones are ossified from a single centre. In each long bone there is a primary centre for the body, or diaphysis; and one or more secondary or epiphysial centres for each extremity. That for the body is the first to appear. The times of union of the epiphyses with the body vary inversely with the dates at which their ossifications begin (with the exception of the fibula) and regulate the direction of the nutrient arteries of the bones. Thus, the nutrient arteries of the bones of the arm and forearm are directed towards the elbow, since the epiphyses at this joint become united with the bodies of the bones before those at the opposite extremities. In the lower limb, on the contrary, the nutrient arteries are directed away from the knee; that is, upwards in the femur, downwards in the tibia and fibula; and in them it is observed that the epiphyses at the upper end of the femur, and those at the lower ends of the tibia and fibula, unite first with the bodies. Where there is only one epiphysis, the nutrient artery is directed towards the other end of the bone.

Parsons * groups epiphyses under three headings, viz. (1) *pressure epiphyses*, appearing at the articular ends of the bones and transmitting 'the weight of the body from bone to bone'; (2) *traction epiphyses*, associated with the insertion of muscles, and 'originally sesamoid structures though not necessarily sesamoid bones'; and (3) *atavistic epiphyses*, representing parts of the skeleton which at one time formed separate bones, but which have lost their function 'and only appear as separate ossifications in early life.'

The description here given of the development and growth of bone is in accordance with the generally accepted view. Macewen † has, however, given another account. He asserts that the osteoblasts are produced by division of the nuclei of the cartilage-cells, and that bone-formation is brought about by these cells, the periosteum taking no part in the process. He concludes that the function of the periosteum in the development of bone is mechanical, and is confined to limiting the degree of growth and deciding its direction.

Applied Anatomy.—A knowledge of the arrangements of the nutrient vessels of bones is important in studying injuries and inflammatory conditions to which bones are liable. The free supply of blood to the epiphyses of the long bones is one reason why necrosis does not extend the whole length of the bone. The outer portion of the compact tissue is supplied by periosteal vessels, many of which reach the periosteum through the attachments of the muscles. Where the muscles are well-developed their blood-supply is abundant, and the periosteum is also well supplied with blood, so that the bones are strongly developed and their ridges prominently marked. Conversely, if the muscular development be poor, the bones are thin and light.

When the periosteum becomes separated by extensive injury or inflammatory exudation, the underlying compact tissue, being deprived of its blood-supply, undergoes *necrosis*, i.e. dies, and the dead part is termed a *sequestrum*. In cases of *acute infective periostitis* the inflammatory process affects the whole or a great portion of the diaphysis of a long bone, and the body of the bone dies very rapidly, especially if the single nutrient artery be thrombosed at the same time. The pus which has formed beneath the periosteum is set free by the bursting of the periosteum or by a timely incision; the periosteum then falls back on the necrosed diaphysis and rapidly forms a layer of new bone surrounding the sequestrum. This layer is called the *involucrum*, and the openings in it through which the pus escapes are termed *cloacæ*.

In another type of inflammation of bone the process begins deeply in the growing portion of the epiphysis, and affects mainly the medullary canal, and is known as *osteomyelitis*; very frequently it coexists with acute infective periostitis and the condition is then spoken of as *acute infective necrosis* of bone, or *acute diaphysitis*. When the medullary cavity is filled with pus, septic thrombosis of the veins in the Haversian canals takes place, and there is great danger of septic emboli being displaced and carried into the general circulation, thus setting up a fatal *pyæmia*; in fact pyæmia is more frequently due to septic bone conditions than to any other cause.

The factors involved in the development and growth of bone must be remembered in dealing with the various injuries and diseases that occur during childhood and adolescence. A bone increases in *circumference* by the deposition on its external surface of new bone from the deeper layer of the periosteum, and in *length* by ossification continuing to extend in the epiphysial cartilage, which goes on growing in advance of the ossifying process.

In *infantile paralysis* where several muscles of a limb become paralysed at a very early period of childhood, the muscles become flaccid and atonic, and their blood-supply is greatly diminished. The periosteal blood-supply suffers and consequently very little

* *Journal of Anatomy and Physiology*, vols. xxxviii., xxxix., and xlii.

† *The growth of bone*, by Sir William Macewen.

fresh osseous tissue is added to the outer surfaces of the bones. In such cases, although the limb continues to grow in length at the epiphysial cartilages, its length is less than that of the normal side, owing to the imperfect nutrition; but the most striking feature about all the long bones of the limb is their extreme thinness.

Since increase in the length of a bone depends on continued growth at the epiphysial cartilages, it is necessary that great care should be taken not to interfere with these in dealing with disease in the neighbourhood of an epiphysis. A knowledge of the periods when the epiphyses join the diaphyses is often of importance in medico-legal enquiries. It is also of practical utility in deciding the nature of an injury in the neighbourhood of a joint, since separation of an epiphysis may simulate a fracture or a dislocation. Further, when amputation through one of the long bones is called for in a young subject the activity of growth at the epiphysial cartilage must be borne in mind. As special cases, amputation through the humerus or tibia may be cited, since in these bones the proximal epiphyses are late in joining the diaphyses. If sufficient allowance be not made for this by cutting long flaps, the portion of the diaphysis remaining will continue to grow till its distal end projects through the stump—a condition known as *conical stump*.

Some of the epiphyses lie entirely within the articular capsules of their corresponding joints, and in such cases disease of the epiphysis is practically synonymous with disease of the joint. The best examples of intra-articular epiphyses are those of the head of the femur and the head of the humerus; the vast majority of cases of tuberculous disease of the hip start as a tuberculous epiphysitis about the intra-articular epiphysial cartilage of the femur; cases of acute septic arthritis of the shoulder- or hip-joints generally have their origins in the intra-articular epiphysial cartilages, and often result in separation of the affected epiphysis. Where an epiphysial cartilage is extra-articular, disease in it does not tend so readily to involve the joint; thus the epiphysial cartilage of the greater trochanter of the femur and that of the upper end of the tibia are outside the joint-capsules, so that if a chronic tuberculous abscess should form in either of these cartilages, its spread into the joint may be prevented by early operation.

Premature arrest of growth of the epiphysial cartilages results in too early junction of the epiphyses with the diaphyses (*premature synostosis*). This brings to an end the growth in length of the bones, and is one of the causes of dwarfism. Persons in whom this has occurred will have the head and trunk of normal size, but the legs and arms disproportionately short though often very strong.

THE CIRCULATING FLUIDS

The **circulating fluids** of the body are the blood and the lymph.

The Blood

The **blood** is an opaque, rather viscid fluid, of a bright red or scarlet colour when it flows from the arteries, of a dark red or purple colour when it flows from the veins. It is salt to the taste, and has a peculiar faint odour and an alkaline reaction. Its specific gravity is about 1·059, and its temperature is generally about 37° C., though varying slightly in different parts of the body.

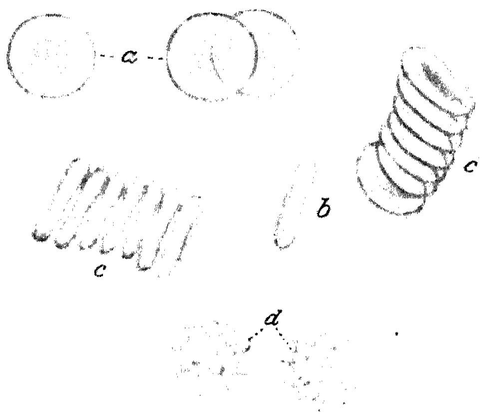
If a thin film of blood be examined under the microscope it is seen to consist of a faintly yellow fluid, the *plasma* or *liquor sanguinis*, in which are suspended numerous minute particles, the *blood-corpuscles*.

The **blood-corpuscles** are of three kinds: (1) coloured corpuscles or erythrocytes, (2) colourless corpuscles or leucocytes, (3) blood-platelets.

1. The **coloured or red corpuscles** (*erythrocytes*) are circular discs, biconcave in profile. The disc has no nucleus, but, in consequence of its biconcave shape, it presents, when seen on the flat, a central area which, when the more prominent peripheral zone of the corpuscle is in focus, appears dark, and so simulates a nucleus (fig. 39, *a*). The corpuscles vary slightly in size even in the same drop of blood, but the average diameter of each is about $7{\cdot}5\mu$, and the thickness about 2μ. Besides these there are certain smaller corpuscles of about one-half of the size just indicated; these are termed *microcytes*, and are very scarce in normal blood; in diseased conditions (e.g. anæmia), however, they are more numerous. It is to the aggregation of the red corpuscles that the blood owes its red hue, although when examined by transmitted light their colour appears to be only a faint reddish yellow. The number of red corpuscles in a cubic millimetre of blood is about 5,000,000 in a man, and 4,500,000 in a woman. Power states that the red corpuscles of an adult would present an aggregate surface of about 3,000 square yards.

If the mesentery of a living animal be spread out and examined under the microscope, the blood is seen to flow in a continuous stream through the vessels, and the corpuscles show no tendency to adhere to each other or to the walls of the vessels. But when blood is drawn and examined on a slide, the corpuscles tend to collect into heaps like rouleaux of coins (fig. 39, *c*). During life the red corpuscles may be seen to change their shape under pressure so as to adapt themselves, to some extent, to the size of the vessel. They are, however, highly elastic, and speedily regain their form when the pressure is removed. They are readily influenced by the medium in which they are placed. In 0·9 per cent. sodium chloride solution, which is isotonic with human blood-plasma, they are unaltered in shape. In hypotonic solutions they swell up, become globular, and finally rupture, owing to the passage of water from the surrounding medium into the corpuscle (*endosmosis*). In hypertonic solutions, e.g. 2 per cent. sodium chloride, water passes in the reverse direction (*exosmosis*) and the corpuscle shrinks and becomes crenated in appearance (fig. 39, *d*). The surface layer of the erythrocyte thus behaves as a membrane which is permeable to water, but not to salts (semi-permeable membrane), and, for this and other reasons, Sharpey Schafer believes that each corpuscle consists of an envelope containing the coloured substance, hæmoglobin. According to another view, the erythrocyte consists of a stroma or sponge-work permeated by the hæmoglobin. The stroma or envelope consists mainly of cholesterol, lecithin, and nucleoprotein.

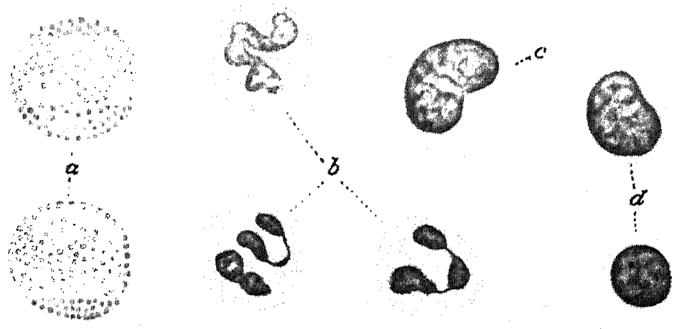
Fig. 39.—Human red blood-corpuscles. × 1500.



a. Seen from the surface. *b*. Seen in profile. *c*. Forming rouleaux. *d*. Rendered crenate by salt solution.

The **colourless corpuscles** or *leucocytes* are of various sizes. In human blood the majority are rather larger than the red corpuscles, and measure about 10μ in diameter. On the average from 7,000 to 12,000 leucocytes are found in each cubic millimetre of blood.

Fig. 40.—Varieties of colourless corpuscles found in human blood, stained with Leishman's stain. × 1500.



a. Eosinophil corpuscles. *b*. Polymorphonuclear leucocytes. *c*. Hyaline cell or macrocyte *d*. Lymphocytes.

They consist of minute nucleated masses of protoplasm, and exhibit several varieties, which are differentiated from each other chiefly by the occurrence or non-occurrence of granules in their protoplasm, and by the staining reactions of these granules when present (fig. 40). (1) The most numerous and important

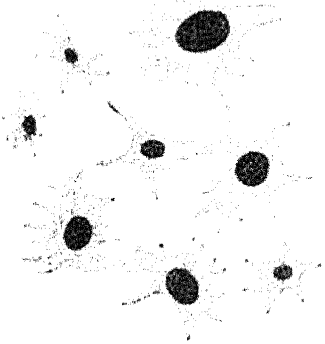
are termed *polymorphonuclear* leucocytes ; they are irregular in shape in the living condition, are possessed of the power of amœboid movement, and contain nuclei which often consist of two or three parts (multipartite) connected together by fine threads of chromatin. When at rest or dead, they are spherical in shape as a rule. The protoplasm contains a number of very fine granules, some of which stain with acid dyes, others with neutral dyes, and are therefore called *oxyphil* or *neutrophil* respectively. They constitute 60 to 70 per cent. of the total number of the colourless corpuscles. (2) A second variety comprises from 1 to 4 per cent. of the leucocytes ; they are larger than the previous kind, and are made up of coarsely granular protoplasm, the granules being highly refractile and grouped round single nuclei of horseshoe shape. The granules stain deeply with eosin, and the cells are therefore often termed *eosinophil* corpuscles. (3) A third variety is called the *hyaline* cell or *macrocyte*. This is usually about the same size as the eosinophil cell, and, when at rest, is spheroidal in shape and contains a single round or oval nucleus. The protoplasm is free from granules, but is not quite

Fig. 41.—Human colourless blood-corpuscle, showing its successive changes of outline within ten minutes when kept moist on a warm stage. (Schofield.)

transparent, having the appearance of ground glass. (4) A fourth kind is designated the *lymphocyte*, because it is identical with the cells derived from the lymph-glands, or other lymphoid tissue. They are the smallest of the leucocytes, and each consists of a spheroidal nucleus surrounded by a small quantity of homogeneous protoplasm. The third and fourth varieties together constitute from 20 to 30 per cent. of the colourless corpuscles, but of the two varieties the lymphocytes are by far the more numerous. Leucocytes having in their protoplasm granules which stain with basic dyes (*basophil*) have been described as occurring in human blood, but they are rarely found except in disease.

The colourless corpuscles are very various in shape in living blood (fig. 41), because many of them have the power of constantly changing their form by protruding finger-shaped or filamentous processes of their substance, by which they move and take up granules from the surrounding medium. In locomotion the corpuscle pushes out a process of its substance—a *pseudopodium*, as it is called—and gradually the rest of the body flows into it. In the same way when any granule or particle comes in its way the corpuscle protrudes a pseudopodium towards it, and then draws the particle into its own substance. By means of these amœboid properties the cells have the power of wandering or emigrating from the blood-capillaries by penetrating between the cells which form their walls and thus finding their way into the extravascular spaces. The solid chemical constituents of leucocytes are nucleo-protein, globulin, fat, cholesterol, lecithin, glycogen, and salts.

Fig. 42.—Blood-platelets. Highly magnified. (After Kopsch.) (From Sharpey-Schafer's Essentials of Histology.)



The **blood-platelets** (fig. 42) are discoid or irregularly shaped, colourless, refractile bodies, much smaller than the red corpuscles. Each contains a central chromatin mass resembling a nucleus. Blood-platelets possess the power of amœboid movement. When blood is shed they rapidly disintegrate and form granular masses, setting free *thrombokinase*, a substance which takes part in the production of fibrin and so is concerned in bringing about the coagulation of the blood. It is doubtful whether platelets exist normally in circulating blood.

The development of the blood-corpuscles is described on pp. 109, 110.

The Lymph

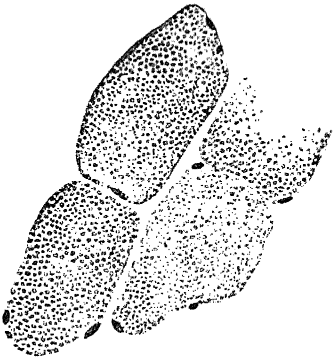
The **lymph** is a transparent, colourless or slightly yellow fluid, which is conveyed into the blood by a set of vessels named *lymphatics*. These vessels arise in nearly all parts of the body as *lymph-capillaries*. They take up the fluid which has exuded from the blood-capillaries for the nourishment of the tissues, and return it into the veins. The greater number of these lymphatic vessels empty themselves into the *thoracic duct*, which ascends in front of the vertebral column and opens into the junction of the internal jugular and subclavian veins on the left side of the root of the neck. The remainder empty themselves into a smaller duct which ends in the corresponding veins on the right side of the neck.

Lymph is a watery fluid of sp. gr. about 1·015; it closely resembles the blood-plasma, but is more dilute. When it is examined under the microscope, leucocytes of the lymphocyte class are found floating in the transparent fluid; they are always increased in number after the passage of the lymph through lymphoid tissue, as in lymph-glands.

MUSCULAR TISSUE

Muscular tissue is composed of bundles of reddish fibres endowed with the property of contractility. There are three varieties of muscle, (1) *striped* or *voluntary*, (2) *unstriped* or *involuntary*, and (3) *cardiac*. The muscles which are concerned with the movements of the bony skeleton, the skeletal muscles, are composed of striped fibres, and are under the control of the will. The muscular coats of the stomach and intestines, uterus, bladder and blood-vessels, on the contrary, are formed of unstriped fibres, and their movements are involuntary. Some striped muscles, however, are not under voluntary control, namely, those forming the walls of the pharynx and upper part of the œsophagus. Cardiac muscle is intermediate in position between the other two varieties. Its fibres are striped, but involuntary, and they differ from both striped and unstriped muscle in structure.

Fig. 43.—A transverse section through human striped muscle fibres. × 255.



The **striped muscular fibres** are arranged in bundles or *fasciculi*, in which the individual fibres are parallel to each other. Each fasciculus has a connective tissue sheath, called the *perimysium*, prolongations of which run into the bundle, binding the fibres together and constituting the *endomysium*. A muscle is composed of a number of fasciculi, held together and surrounded by connective tissue which is known as the *epimysium*. The fasciculi are of different sizes in different muscles, and are for the most part placed parallel to each other, though they usually converge towards the tendinous attachments. The connective tissue framework of the muscle contains the blood-vessels and nerves which supply it.

A *muscular fibre* consists of a soft contractile substance, enclosed in a tubular sheath called the *sarcolemma*. The fibres are cylindrical or prismatic in shape (fig. 43), and are of no great length, not exceeding as a rule 40 mm. Their breadth varies in man from 0·01 mm. to 0·1 mm. As a rule, the fibres do not divide or anastomose; but occasionally, especially in the tongue and facial muscles, they may be seen to divide into several branches. In the substance of the muscle, the fibres end by tapering extremities which are joined to the ends of other fibres by the sarcolemma. Where a muscle joins its tendon, the sarcolemma covering the end of each muscle-fibre blends with a corresponding group of the fine fibres of the tendon. The muscular substance of the fibre can readily be made to retract from the point of junction. The areolar tissue between the fibres is prolonged

ANATOMY

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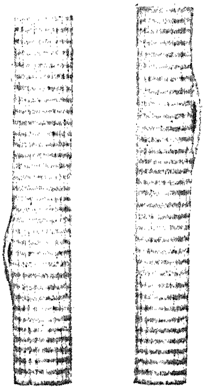
IN ADMIRATION OF HIS GREAT TALENTS AND IN REMEMBRANCE OF MANY ACTS OF KINDNESS SHOWN TO THE ORIGINAL AUTHOR OF THE BOOK FROM AN EARLY PERIOD OF HIS PROFESSIONAL CAREER

into the tendon, so as to form a kind of sheath around the tendon-bundles for a longer or shorter distance. When muscular fibres are attached to skin or mucous membranes, this sheath becomes continuous with the areolar tissue of these structures.

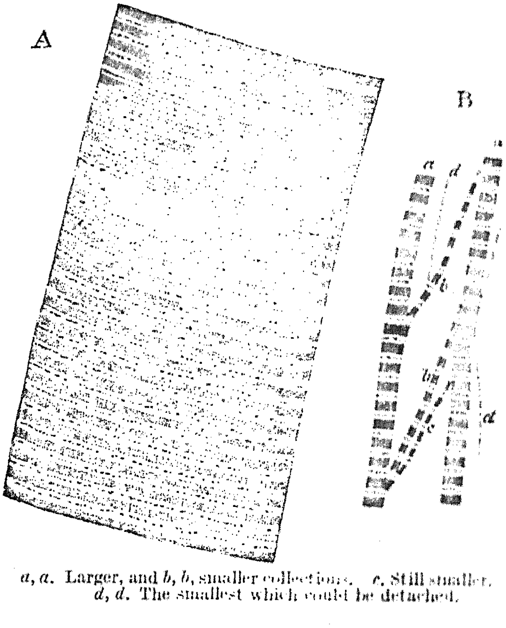
Fig. 44.—Striped muscle-fibres from the tongue of a cat. × 250.



The *sarcolemma*, or tubular sheath of the fibre, is a transparent, elastic, and apparently homogeneous membrane of considerable toughness, so that it sometimes remains entire when the included substance is ruptured. On the internal surface of the sarcolemma in mammalia, and also in the substance of the fibre in frogs, elongated nuclei are seen, and surrounding each of these is a little granular protoplasm.

Upon examination of a voluntary muscular fibre by transmitted light, it is found to be marked by alternate light and dark bands or striæ, which pass transversely across the fibre (fig. 44). When examined by polarised light the dark bands are found to be doubly refracting (anisotropic), while the clear stripes are singly refracting (isotropic). The dark and light bands are of nearly equal breadth, and alternate with great regularity; they vary in breadth from about 1μ to 2μ. When the fibre is deeply focussed a dark line may be seen running in the middle of the clear stripe. This is known as *Dobie's line* or *Krause's membrane*. In fibres which are in the extended condition the dim stripe is often seen to be divided by a clearer line, *Hensen's line*.

Fig. 45.—A. A portion of a medium-sized human muscular fibre. Magnified nearly 800 diameters. B. Separated bundles of fibrils, equally magnified. (From Quain's Elements of Anatomy.)



a, a. Larger, and *b, b,* smaller collections. *c.* Still smaller. *d, d.* The smallest which could be detached.

Under high magnification there are indications that the striped muscle-fibre is made up of a large number of fibrils, known as *sarcostyles*, together with an interfibrillar material, or *sarcoplasm* (fig. 45, B). When a fibre is treated with weak acid it becomes clearer, and the sarcoplasm is visible as fine, longitudinal, parallel lines. At the junction of the dim and clear stripes these lines often show bead-like enlargements in the extended condition of the fibre. Examination of transverse sections of individual fibres shows that each sarcostyle is surrounded by sarcoplasm, and that the sarcostyles are arranged in groups called *muscle-columns*, the groups being separated by a relatively larger amount of sarcoplasm than the separate fibrils. The sections of muscle-columns, defined in this way, constitute what are known as *Cohnheim's areas*.

When the sarcostyles are separated by suitable methods it becomes evident that each exhibits alternate dim and clear portions, with Dobie's and Hensen's lines, and that the striped appearance of the fibre is due to the apposition of the corresponding segments of the fibrils of which it is composed.

Sharpey Schafer has worked out the minute anatomy of muscular fibre, particularly in the wing-muscles of insects, which are peculiarly adapted for this purpose on account of the relatively large size of the sarcostyles and the ease with which they can be separated. In the following description that given by Sharpey Schafer is closely followed.

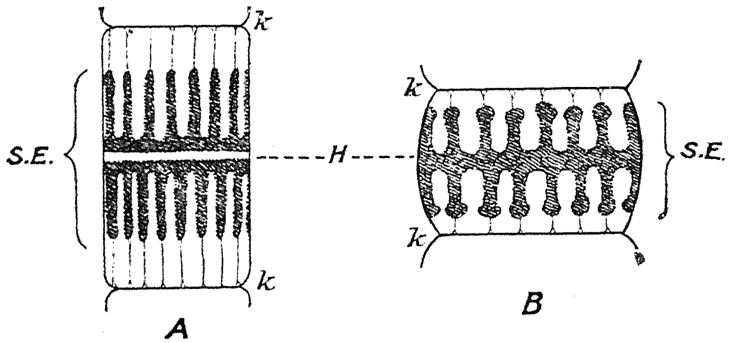
A sarcostyle may be said to be made up of successive portions, each of which is termed a *sarcomere.* The sarcomere is situated between two membranes of Krause, and consists of (1) a central dark part, which forms a portion of the dark band of the whole fibre, and (2) a clear area at either end, each forming, with the corresponding clear part of the adjacent sarcomere, the light band of the fibril. The central dark segment really consists of two parts, and when the fibre is stretched these two parts become separated from each other at the line of Hensen (fig. 46, A). The clear areas are well marked in the extended sarcostyle, but in the contracted sarcostyle they are small or altogether absent (fig. 46, B).

The central dim portion, or *sarcous element,* does not lie free in the sarcomere, for when the sarcostyle is stretched, very fine lines, which are probably septa, may be seen running through the clear portion from the sarcous element to the membrane of Krause.

Sharpey Schafer explains these phenomena in the following way. He considers that each dim segment contains a number of longitudinal channels, which open into the clear part towards the membrane of Krause but are closed at the line of Hensen. When the muscular fibre contracts the clear part of the muscular substance passes into these channels or tubes, and is therefore hidden from sight, but at the same time it swells up the sarcous element and widens and shortens the sarcomere.

FIG. 46.—A diagram of a sarcomere. (After Sharpey Schafer.)

A. In a moderately extended condition. B. In a contracted condition.



H. Line of Hensen. *k, k.* Membranes of Krause. S.E. Sarcous element.

When, on the contrary, the fibre is extended, this clear substance is driven out of the tubes and collects between the sarcous element and the membrane of Krause, and gives the appearance of the light part between these two structures; by this means it elongates and narrows the sarcomere.

Sharpey Schafer has shown that, if this view be correct, it harmonises the contraction of muscle with the amœboid action of protoplasm. In an amœboid cell there is, according to one view of the structure of protoplasm, a framework of spongioplasm, enclosing in its meshes a clear substance, hyaloplasm. Under stimulation the hyaloplasm passes into the pores of the spongioplasm; without stimulation it tends to pass out, as in the formation of pseudopodia. In muscle there is the same thing, viz. a framework of spongioplasm—the substance of the dim segment; and this encloses a clear hyaloplasm, the clear substance of the sarcomere. During contraction of the muscle—i.e. under stimulation—this clear substance passes into the pores of the spongioplasm; while during extension of the muscle—i.e. when there is no stimulation—it tends to pass out of the spongioplasm. In this way the contraction is brought about; under stimulation the protoplasmic material (the clear substance of the sarcomere) recedes into the sarcous element, causing the sarcomere to widen out and shorten. The contraction of the muscle is merely the sum total of this widening out and shortening of these bodies.

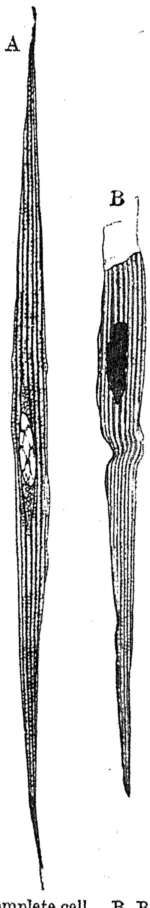
Vessels and nerves of striped muscle.—The *capillaries* of striped muscle are very abundant, and form a sort of rectangular network, the branches of which run longitudinally in the endomysium between the muscular fibres, and are joined at short intervals by transverse anastomosing branches. In the red muscles of the rabbit dilatations occur on the transverse branches of the capillary network. The

larger vascular channels, arteries and veins, are found only in the perimysium, between the muscular fasciculi. *Nerves* are profusely distributed to striped muscle. Their mode of termination is described in the chapter on Neurology. *Lymphatic vessels* do not occur in striped muscle, though they have been found in tendons and in the sheaths of the muscles.

The **unstriped, plain,** or **involuntary muscle** is found in the following situations—in the lower half of the œsophagus and the whole of the remainder of the gastro-intestinal tube; in the trachea and bronchi; in the gall-bladder and common bile-duct; in the large ducts of the salivary and pancreatic glands; in the pelvis and calyces of the kidney, the ureter, bladder, and urethra; in the female sexual organs—viz. the ovary, the uterine tubes, the uterus (enormously developed in pregnancy), the vagina, the broad ligaments, and the corpora cavernosa of the clitoris; in the male sexual organs—viz. the Dartos of the scrotum, the ductus deferentes and epididymes, the vesiculæ seminales, the prostate, and the corpora cavernosa of the penis and urethra; in the capsule and trabeculæ of the spleen; in the mucous membranes, forming the muscularis mucosæ; in the skin, forming the Arrectores pilorum, and also in the sweat-glands; in the mammary glands; in the arteries, veins, and lymphatics; in the iris and the ciliary muscle.

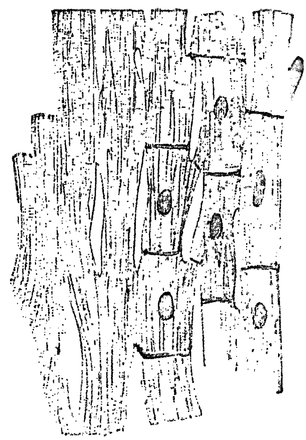
Unstriped or plain muscle is made up of spindle-shaped cells (fig. 47), collected into bundles and held together by a cement-substance. These bundles are further aggregated into larger fasciculi, or sheets, bound together by ordinary connective tissue.

FIG. 47.—Muscle-fibres from the small intestine. (From Quain's Elements of Anatomy, vol. ii. pt. i., Microscopic Anatomy, by Sir Edward Sharpey Schafer.)



A. Complete cell. B. Broken cell showing delicate external layer.

FIG. 48.—Anastomosing muscular fibres of the heart seen in a longitudinal section. On the right the limits of the separate cells with their nuclei are exhibited somewhat diagrammatically. (Schweigger-Seidel.)



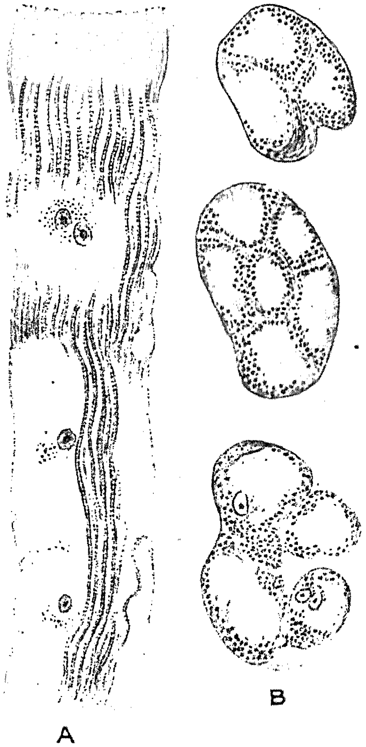
The cells are elongated, spindle-shaped, and nucleated, and are of various sizes, averaging from 40μ to 80μ in length, and 6μ to 7μ in breadth. On transverse section they are more or less polyhedral in shape, from mutual pressure. Each presents a faint longitudinal striation and consists of an elastic cell-wall containing the contractile substance, and an oval or rod-like nucleus. A centriole lies close to the nucleus. The fibres are attached to one another by a certain amount of interstitial cement-substance which reduces nitrate of silver, but in some regions, e.g. the muscular coats of the intestines, the muscle-cells are also connected by 'bridges' similar to those which occur in the prickle-cells of the epidermis.

Sheets of smooth muscle frequently exhibit rhythmical contractions, which are more sluggish than the contractions of striped muscle and in many cases travel

along the membrane in the form of waves. Such waves are well marked in the wall of the intestine. Contraction is often excited by a mechanical stimulus, as distension, for example, in the urinary bladder.

The **cardiac muscular tissue.**—The fibres of the heart differ very remarkably from those of other striped muscles. They are striated both transversely and longitudinally, but the striation, as compared with that of striped muscle, is faint and indistinct. The fibres are made up of quadrangular cells joined end to end so as to form a syncytium (fig. 48). Each cell contains a clear oval nucleus, situated near its centre. Many of the cells branch or divide, the subdivisions uniting with offsets from other cells, and thus producing an anastomosis of the fibres. The connective tissue between the bundles of fibres is much less than in ordinary striped muscle, and no sarcolemma has been proved to exist.

FIG. 49.—Purkinje's fibres from the sheep's heart. × 250.



A. In longitudinal section.
B. In transverse section.

Purkinje's fibres (fig. 49).—Between the endocardium and the ordinary cardiac muscle are found, embedded in a small amount of connective tissue, peculiar fibres known as *Purkinje's fibres.* They are associated with the terminal distributions of the atrioventricular bundle. The fibres are very much larger in size than the cardiac cells and differ from them in several ways. In longitudinal section they are quadrilateral in shape, being about twice as long as they are broad. The central portion of each fibre contains one or more nuclei and is made up of granular protoplasm, with no indication of striation, while the peripheral portion is fibrillated and has transverse striations. The fibres are intimately connected with each other, possess no definite sarcolemma, and do not branch. They form a considerable portion of the moderator band in the heart of the sheep.

The **atrioventricular bundle** (see chapter on Angiology) is composed of cells which differ from ordinary cardiac muscle-cells in being more spindle-shaped. They are, moreover, more loosely arranged and have a richer vascular supply than the rest of the cardiac muscle.

Development of muscle-fibres.—Voluntary muscular fibres are developed from the mesoderm, the embryonic cells of which elongate, show multiplication of nuclei, and eventually become striated; the striation is first obvious at the side of the fibre, spreads around the circumference, and ultimately extends to the centre. The nuclei, at first situated centrally, gradually pass out to assume their final position immediately beneath the sarcolemma. In the case of involuntary muscle the mesodermal cell assumes a pointed shape at the extremities and becomes flattened, the nucleus also lengthening out to its permanent rod-like form.

NERVOUS TISSUE

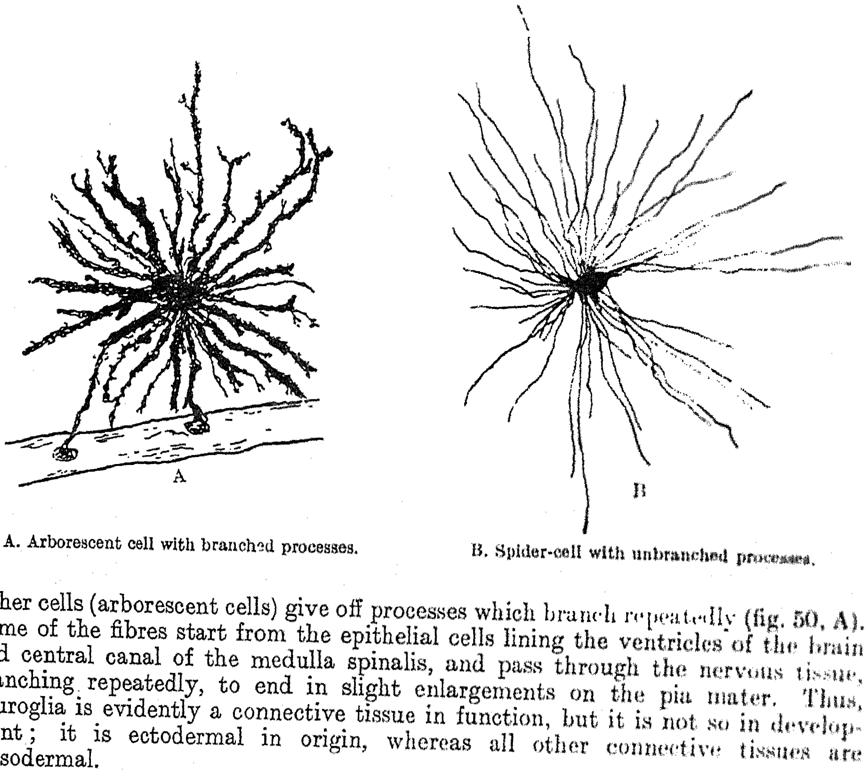
The **nervous tissues** of the body comprise the brain, the medulla spinalis or spinal cord, the cerebral, spinal, and sympathetic nerves, and the ganglia connected with them.

The nervous tissues are composed of *nerve-cells* and their various processes, together with a supporting tissue called *neuroglia*, which, however, is found only in the brain and medulla spinalis. Certain long processes of the nerve-cells are of special importance, and it is convenient to consider them apart from the cells; they are known as *nerve-fibres.*

To the naked eye a difference is obvious between certain portions of the brain and medulla spinalis, viz. the *grey* substance, and the *white* substance. The grey substance is largely composed of nerve-cells, while the white substance contains only their long processes, the nerve-fibres. It is in the former that nervous impressions are received, stored, and transformed into efferent impulses, and by the latter that they are conducted. Hence the grey substance forms the essential constituent of all the ganglionic centres, both those in the isolated ganglia and those aggregated in the brain and medulla spinalis; while the white substance forms the bulk of the commissural portions of the nerve-centres and the peripheral nerves.

Neuroglia, the peculiar variety of connective tissue which binds together the true nervous constituents of the brain and medulla spinalis, consists of cells and fibres. Some of the cells (spider-cells) are stellate in shape, with ill-defined cell-body, and their fine processes become neuroglia fibres, which extend radially and unbranched (fig. 50, B) among the nerve-cells and fibres which they aid in supporting.

FIG. 50.—Neuroglia-cells of the brain shown by Golgi's method. (After Andriezen.) (From Sharpey Schafer's Essentials of Histology.)



A. Arborescent cell with branched processes. B. Spider-cell with unbranched processes.

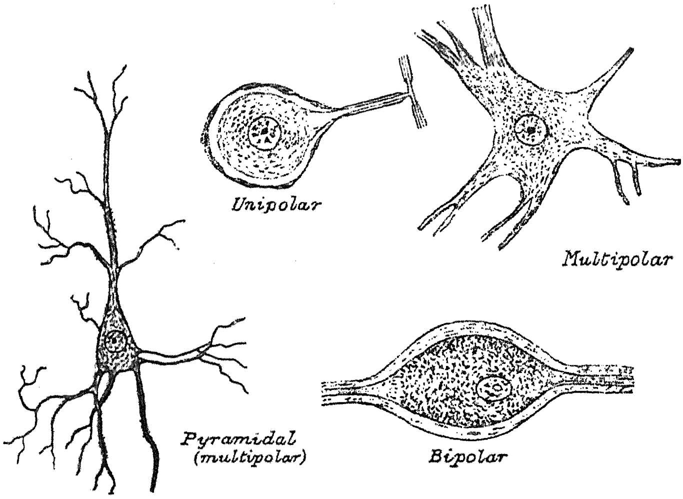
Other cells (arborescent cells) give off processes which branch repeatedly (fig. 50, A). Some of the fibres start from the epithelial cells lining the ventricles of the brain and central canal of the medulla spinalis, and pass through the nervous tissue, branching repeatedly, to end in slight enlargements on the pia mater. Thus, neuroglia is evidently a connective tissue in function, but it is not so in development; it is ectodermal in origin, whereas all other connective tissues are mesodermal.

Nerve-cells (fig. 51) are largely aggregated in the grey substance of the brain and medulla spinalis, but smaller collections of these cells also form the swellings, called *ganglia,* seen on many nerves. These latter are found chiefly upon the spinal and cerebral nerve-roots and in connexion with the sympathetic nerves.

Nerve-cells vary in shape and size, and have one or more processes. They may be divided for purposes of description into three groups according to the number of processes which they possess. (1) Unipolar cells are found in the spinal ganglia; the single process, after a short course, divides in a T-shaped manner (fig. 51). These cells are bipolar in embryonic life, but, as development proceeds, the two processes approach one another and become fused for a short distance. In the spinal ganglia of fish the cells are bipolar throughout life. (2) Bipolar cells (fig. 51) are found, in the adult, in the retina, and in the ganglion spirale and ganglion vestibulare of the acoustic nerve. In some cases where two fibres are

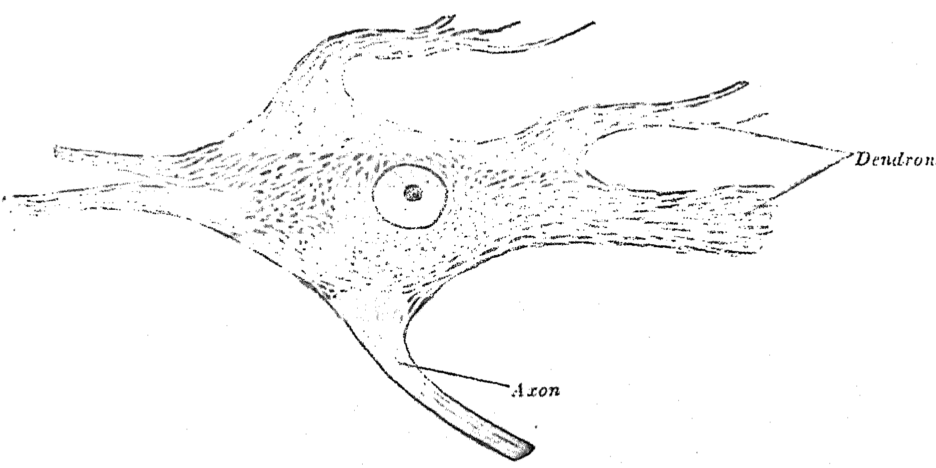
apparently connected with a cell, one of the fibres is really derived from an adjoining nerve-cell and is passing to end in a ramification around a unipolar cell, or, again, it may be coiled spirally round the nerve-process which is issuing from the cell. (3) Multipolar cells are pyramidal or stellate in shape, and characterised by the

FIG. 51.—Various forms of nerve-cells.



numerous processes which issue from them. The processes are of two kinds: one of them is termed the *axis-cylinder process* or *axon* because it becomes the axis-cylinder of a nerve-fibre (figs. 52, 53, 54). The others are termed the *protoplasmic processes* or *dendrons*; they begin to divide and subdivide as soon as they emerge from the cell, and finally end in minute twigs. The axons of certain multipolar

FIG. 52.—A motor nerve-cell from the anterior horn of the medulla spinalis of an ox, stained with methylene blue. ×500. The spindle-shaped Nissl's granules are shown. The dendrons and axon are broken off close to the cell.



cells terminate by arborescence close to the cell-bodies; such cells were called by Golgi multipolar cells of the second type.

The body of the nerve-cell is known as the *cyton*. In fixed and stained preparations it consists of a finely fibrillated protoplasmic material in which there are occasionally patches of a deeper tint, caused by the aggregation of pigment-granules at the sides of the nuclei, as in the substantia nigra and locus cæruleus of the brain.

The protoplasm also contains peculiar angular masses of granules, which stain deeply with basic dyes such as methylene blue ; these are known as *Nissl's spindles* (fig. 52). They extend into the dendritic processes but not into the axis-cylinder ; the small clear area at the point of exit of the axon is termed the *cone of origin*. These bodies disappear (*chromatolysis*) during fatigue or after section of the nerve-fibre connected with the cell. They are supposed to represent a store of nervous

FIG. 53.—A pyramidal cell from the cerebral cortex of a mouse. Golgi method. (After Ramón y Cajal.)

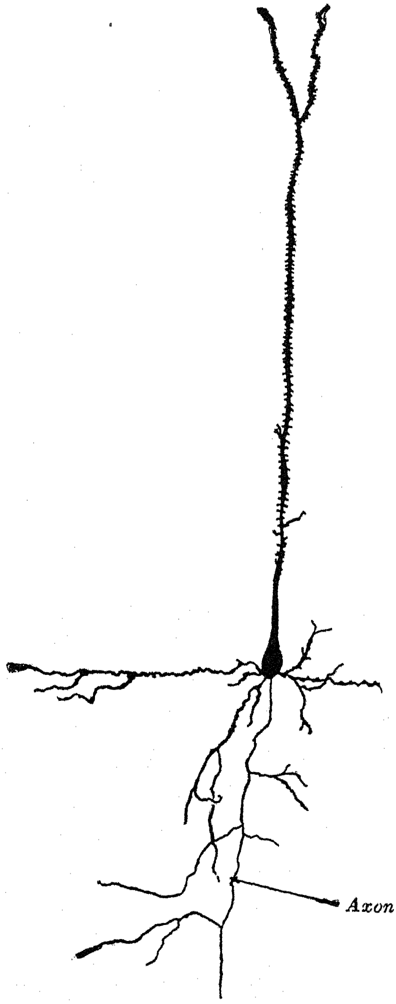
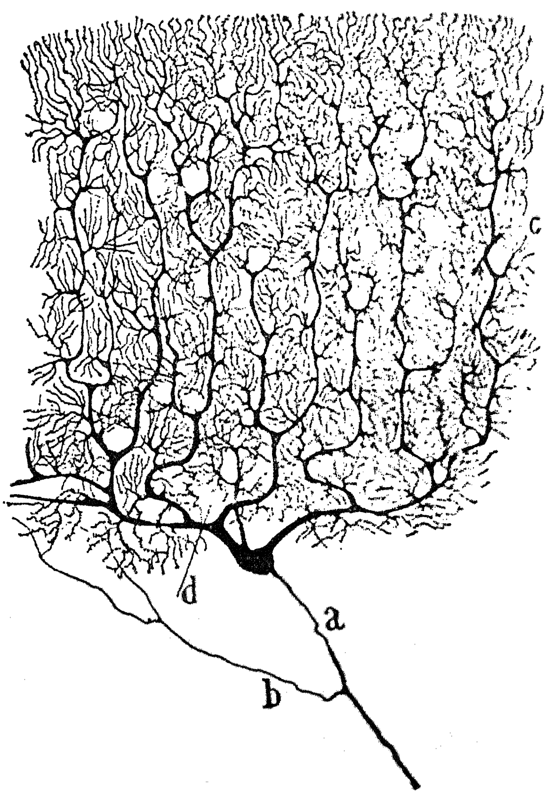


FIG. 54.—A cell of Purkinje from the cerebellum. Golgi method. (Ramón y Cajal.)



a. Axon. *b*. Collateral. *c* and *d*. Dendrons.

energy, and in various mental diseases are deficient or absent. The nucleus is, as a rule, a large, well-defined body, with a relatively small amount of chromatin, and contains a well-marked nucleolus.

In addition to the protoplasmic network described above, each nerve-cell may be shown to have delicate neurofibrils running through its substance (fig. 55) ; these fibrils are continuous with the fibrils of the axon, and are believed to convey nerve-impulses. A *pericellular network* of fine branching fibres is a characteristic feature of many nerve-cells.

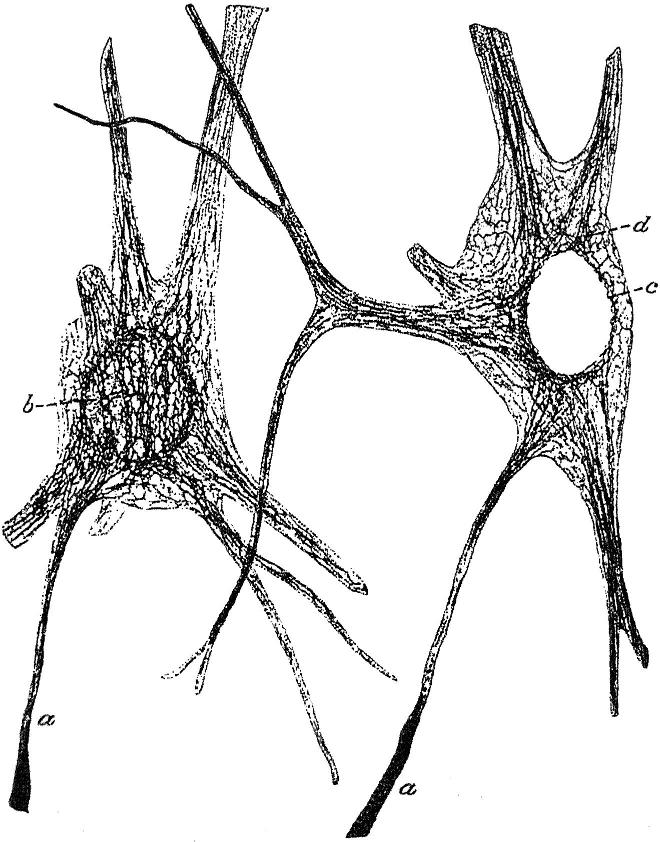
Mott and Marinesco have shown that, when living nerve-cells are examined by the dark ground illumination method, neither Nissl's bodies nor fibrils of any kind can be seen. The constancy of the occurrence of both these structures in fixed

preparations, however, indicates that they represent something specific in the living cell.

Nerve-fibres are found universally in the peripheral nerves, and in the white substance of the brain and medulla spinalis. They are of two kinds—viz. *medullated* or *white* fibres, and *non-medullated* or *grey* fibres.

The *medullated fibres* form the white part of the brain and medulla spinalis, and also the greater part of every cerebral and spinal nerve, and give to these structures their opaque, white aspect. When perfectly fresh they appear to be homogeneous; but soon after removal from the body each fibre presents, when examined by transmitted light, a double outline or contour, as if consisting of two parts (fig. 56). The central portion is named the *axis-cylinder*; around this is a sheath of fatty

FIG. 55.—Nerve-cells of a kitten, showing neurofibrils. (Ramón y Cajal.)



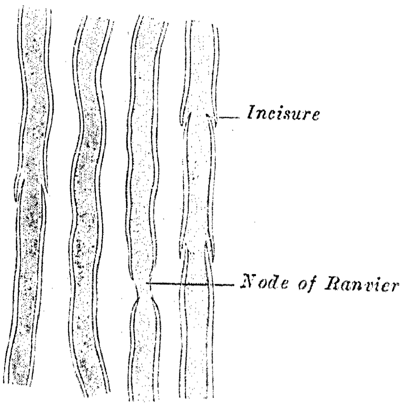
a. Axon. *b*. Cyton. *c*. Nucleus. *d*. Neurofibrils.

material, staining black with osmic acid, named the *white substance of Schwann* or *medullary sheath*, which gives to the fibre its double contour; and the whole is enclosed in a delicate membrane, the *neurolemma*, *primitive sheath*, or *nucleated sheath of Schwann* (fig. 57). Medullated nerve-fibres vary in diameter from 2μ to 16μ.

The *axis-cylinder* is the essential part of the nerve-fibre, and is always present; the medullary sheath and the neurolemma are occasionally absent, especially at the origin and termination of the nerve-fibre. The axis-cylinder undergoes no interruption from its origin in the nerve-centre to its termination, and must be regarded as a direct prolongation of a nerve-cell. Nerve-fibres in the white substance of the brain and medulla spinalis give off twigs known as *collaterals*. These arise from the main fibre at right angles to its course and run into the grey substance, where they terminate by arborisation. The axis-cylinder constitutes about one-half or one-third of the nerve-fibre, being greater in proportion in the fibres of the central organs than in those of the nerves. It is quite transparent, and is therefore

indistinguishable in a perfectly fresh and natural state of the nerve. It is made up of exceedingly fine fibrils (figs. 57 and 58), which stain darkly with gold chloride, and at its termination may be seen to break up into these fibrils. The axis-cylinder is said by some to be enveloped in a special reticular sheath, which separates it from the medullary sheath, and is composed of a substance called *neurokeratin.* The more common opinion is that this network or reticulum is contained in the white substance of Schwann, and by some it is believed to be produced by the action of the reagents employed to show it.

FIG. 56.—Medullated nerve-fibres. × 350.



The *medullary sheath* or *white substance of Schwann* (fig. 57) is regarded as being a fatty material in a fluid state, which insulates and protects, or possibly supplies nutriment to, the essential part of the nerve—the axis-cylinder. As a general rule its thickness is proportional to the size of the axis-cylinder, and is such that it forms about half of the total area of the cross section of the fibre. Its continuity is interrupted at intervals of about 1 mm., giving to the fibre the appearance of constriction at these points; these are known as the *nodes of Ranvier* (figs. 56 and 57). The portion of nerve-fibre between two nodes is called an *internodal segment.* The neurolemma or primitive sheath is not interrupted at the nodes, but passes over them as a continuous membrane. Some observers, however, believe that the neurolemma of one internodal segment is connected with that of the adjacent segment at the node by cement-substance. If the fibre be treated with silver nitrate the reagent penetrates the neurolemma at the nodes, and, on exposure to light, reduction takes place, giving rise to the appearance of black crosses, *Ranvier's crosses,* on the axis-cylinder. There may also be seen transverse lines beyond the nodes termed *Frommann's lines* (fig. 59); the significance of these is not understood. In addition to these interruptions, oblique clefts or *incisures* may be seen in the medullary sheath, subdividing it into irregular portions, which are termed *medullary segments,* or *segments of Lantermann* (figs. 56 and 57); there is reason to believe that these clefts are artificially produced in the preparation of the specimens. Medullated nerve-fibres, when examined in the fresh condition, frequently present a beaded or varicose appearance, due to

FIG. 57.—A diagram of longitudinal sections of medullated nerve-fibres. Osmic acid.

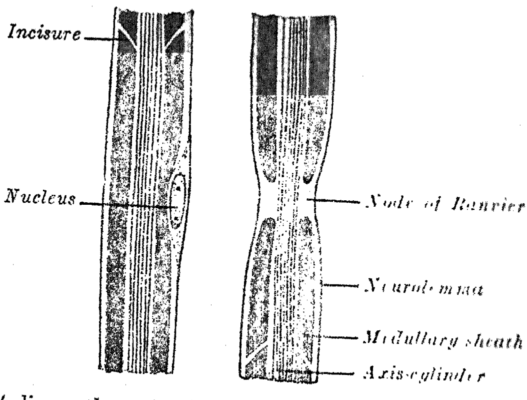
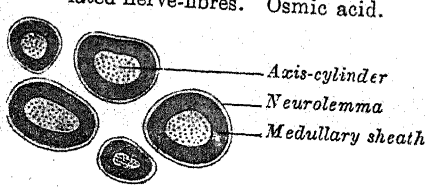


FIG. 58.—Transverse sections through medullated nerve-fibres. Osmic acid.



EMBRYOLOGY

THE term **Embryology,** in its widest sense, comprises the various changes which take place during the growth of an animal from the egg to the adult condition; it is, however, usually restricted to the phenomena which occur before birth.

In vertebrate animals the development of a new being normally takes place when a female germ-cell or *ovum* has been fertilised by a male germ-cell or *spermatozoon*. The ovum is a nucleated cell, and the complicated changes by which the various tissues and organs of the body are formed from it, after it has been fertilised, are the result of two general processes, viz. *segmentation* and *differentiation* of cells. Thus, the fertilised ovum undergoes repeated segmentation into a number of cells which at first closely resemble one another, but are, sooner or later, differentiated into two groups: (1) *somatic cells*, the function of which is to build up the various tissues of the body; and (2) *germinal cells*, which are ultimately imbedded in the genital glands (ovaries and testes), and destined for the perpetuation of the species.

Having regard to the main purpose of this work, it is impossible, in the space available in this chapter, to describe or illustrate fully, all the changes which occur during the development of the human body. Only the principal facts are given, and the student is referred for further details to one or other of the text-books * on embryology.

THE OVUM

The ova are derived from the primitive germ-cells which are situated in the substance of the ovaries; each primitive germ-cell gives rise, by repeated divisions, to a number of smaller cells termed *oögonia* from which the *ova* or *primary oocytes* are developed.

Human ova measure about 0·1 mm. in diameter, and are contained within the Graafian follicles of the ovaries †; as a rule each follicle contains one ovum, but sometimes two or more are present. By the enlargement and subsequent rupture of a follicle at the surface of the ovary, an ovum is liberated and enters the uterine tube through which it is conveyed to the cavity of the uterus. Unless it be fertilised it is discharged from the uterus, but if fertilisation takes place it is retained there and developed into a new being.

In appearance and structure the ovum (fig. 61) differs little from an ordinary cell (p. 1), but distinctive names are given to its several parts; thus, the cell-substance is known as the *yolk* or *oöplasm*, the nucleus as the *germinal vesicle*, and the nucleolus as the *germinal spot*. The ovum has a thick, transparent envelope named the *zona striata* or *zona pellucida*, and when the ovum is liberated from the Graafian follicle, several layers of cells, derived from those of the follicle, adhere to the outer surface of the zona striata, and collectively constitute the *corona radiata*.

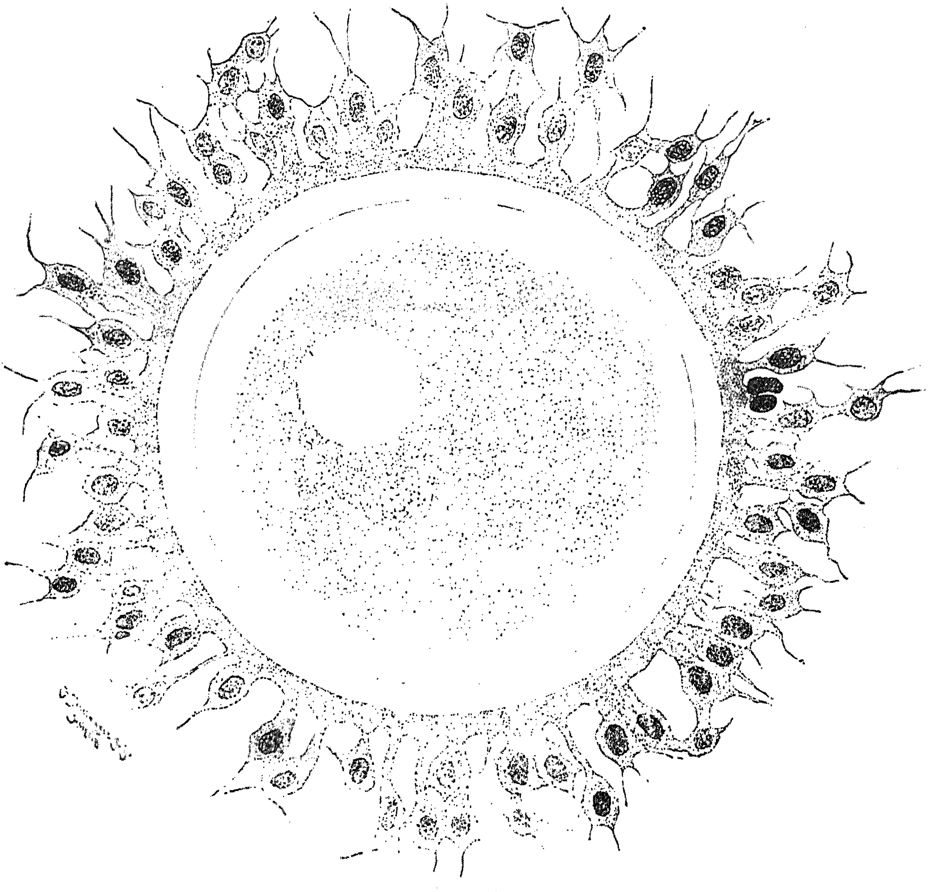
The **yolk** comprises (1) *cytoplasm* similar to that of the ordinary animal cell (p. 1), and frequently termed the *formative yolk*; (2) *deuteroplasm* or *nutritive yolk*, which consists of numerous round granules of fatty and albuminoid substances imbedded in the cytoplasm. In the mammalian ovum the deuteroplasm is extremely small in amount, and nourishes the embryo in the early stages of its

* *Manual of Human Embryology*, Keibel and Mall; *Handbuch der vergleichenden und experimentellen Entwickelungslehre der Wirbeltiere*, Oskar Hertwig; *Human Embryology and Morphology*, Arthur Keith, 1921; *Traité d'Embryologie des vertébrés*, A. Brachet, 1921; *Vertebrate Embryology*, Jenkinson; *The Physiology of Reproduction*, Marshall.

† See description of the ovary under Splanchnology.

development only, whereas in the egg of the bird there is sufficient to supply the chick with nutriment throughout the whole period of incubation. The mode of distribution of the deuteroplasm within the egg varies in different animals; in some it is almost uniformly dispersed throughout the cytoplasm; in some it is centrally placed and surrounded by the cytoplasm; in others it is accumulated at the lower pole of the ovum, while the cytoplasm occupies the upper pole. A *centrosome* and *centriole* are present and lie in the immediate neighbourhood of the nucleus.

FIG. 61.—A human ovum examined fresh in the liquor folliculi. ×500. (Waldeyer.)



The zona pellucida is seen as a thick clear girdle surrounded by the cells of the corona radiata. The ovum shows a central granular deuteroplasmic area and a peripheral clear cytoplasmic layer, and encloses the germinal vesicle, in which the germinal spot is indistinctly seen.

The **nucleus** or **germinal vesicle** is a large spherical body which usually occupies an excentric position in the yolk. Its structure is that of an ordinary cell-nucleus, viz. it consists of a reticulum or karyomitome the meshes of which are filled with karyoplasm, while connected with, or imbedded in, the reticulum are a number of chromatin masses or chromosomes, which may present the appearance of a skein or may assume the form of rods or loops. The nucleus is enclosed by a delicate nuclear membrane, and contains in its interior a well-defined nucleolus or germinal spot.

THE COVERINGS OF THE OVUM

The **zona striata** or **zona pellucida** (fig. 61) is a thick membrane, which, under the higher powers of the microscope, is seen to be radially striated. Thomson * describes the zona pellucida as consisting of (*a*) an inner, homogeneous layer which

* Professor Arthur Thomson, *Journal of Anatomy*, vol. liii. 1919.

is derived from the ovum, and (*b*) an outer, fibrillar layer formed by the felting of the basal fibres of the innermost cells of the corona radiata. He is also of opinion that there is distinct evidence of a *vitelline membrane* within the zona pellucida.

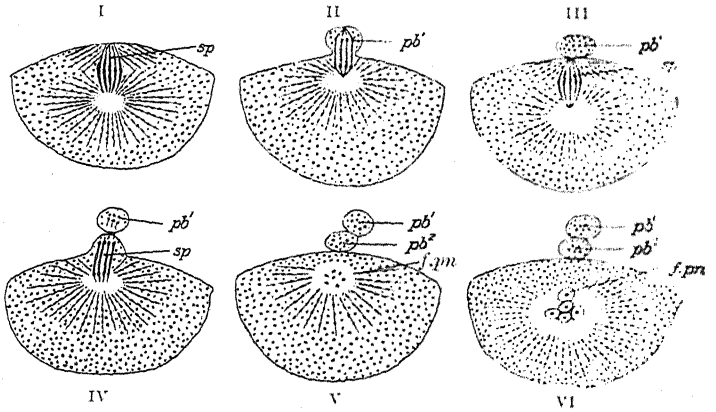
The **corona radiata** (fig. 61) consists of two or three strata of cells which are derived from the cells of the Graafian follicle, and adhere to the outer surface of the zona striata when the ovum is set free from the follicle: the cells are radially arranged around the zona, those of the innermost layer being columnar in shape. The cells of the corona radiata soon disappear; in some animals they secrete, or are replaced by, a layer of protein, which may assist in protecting and nourishing the ovum.

The phenomena attending the discharge of the ova from the Graafian follicles are described with the anatomy of the ovaries.

THE MATURATION OF THE OVUM

Before an ovum or primary oöcyte can be fertilised it must undergo a process of *maturation* or *ripening* (fig. 62). This process consists of a heterotypical division of the ovum into two cells, followed by a homotypical division of the two cells into four. Three of the four cells are small, incapable of further development,

FIG. 62.—The formation of the polar bodies in Asterias glacialis. (Slightly modified from Hertwig.)



In fig. I the polar spindle (*sp*) has advanced to the surface of the egg. In fig. II a small elevation (pb^1) is formed which receives half of the spindle. In fig. III the elevation is constricted off, forming the first polar body (pb^1), and a second spindle is formed. In fig. IV is seen a second elevation which in fig. V has been constricted off as the second polar body (pb^2). Out of the remainder of the spindle (*f.pn* in fig. VI) the female pronucleus is developed.

and are named *polar bodies* or *polocytes*. The fourth cell is large; it is named the *mature ovum*, and is devoid of a centrosome. Its nucleus, as the result of the heterotypical division, contains only one-half of the number of chromosomes present in the nucleus of the primary oöcyte. The nucleus of the mature ovum is named the *female pronucleus*.

In most vertebrates the heterotypical division occurs before the ovum or primary oöcyte is liberated from the ovarian or Graafian follicle, and the homotypical division after a spermatozoön has penetrated the zona pellucida. Thomson * has submitted evidence to show that in man both polar bodies are extruded before the ovum is liberated from the Graafian follicle; in other words, the process of maturation is completed before the ovum has been subjected to the influence of a spermatozoön.

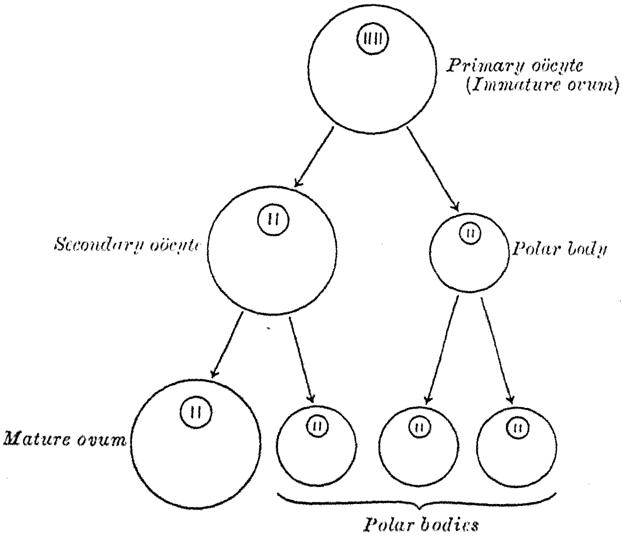
The process of maturation of the ovum has been carefully studied in the ova of some of the lower animals, to which the following description applies.

It was pointed out on page 2 that the number of chromosomes found in the nucleus is constant for all the cells in an animal of any given species, and that in

* *Loc. cit.*

man the number is probably twenty-four.* This applies not only to the somatic cells but to the primitive ova and their descendants. For the purpose of illustrating the process of maturation a species may be taken in which the number of nuclear chromosomes is four (fig. 63). If an ovum from such be observed at the beginning of the maturation process, the usual achromatic spindle is seen lying close to and parallel with the surface of the ovum, with the four chromosomes arranged at its

FIG. 63.—A diagram showing the reduction in number of the chromosomes during the maturation of the ovum. The first division is heterotypical, the second homotypical.



equator. The spindle then rotates so that its long axis is radial, and the first or heterotypical division takes place; two chromosomes pass to either end of the spindle, those at the periphery producing a surface elevation which is constricted off as the *first polar body*. The other two chromosomes are retained in the ovum, which is now termed a *secondary oöcyte*. Without passing through a resting stage the secondary oöcyte undergoes homotypical division, the two chromosomes each dividing into two, which travel to the ends of the spindle. A *second polar body* is segmented off, and the *mature ovum*, with two chromosomes gathered into a newly formed nucleus, remains. The first polar body frequently divides in a homotypical manner while the second is being formed, and as a final result four cells are produced, viz. the mature ovum and three polar bodies, each of which contains two chromosomes, i.e. one-half of the number present in the nuclei of the somatic cells of members of the same species.

THE SPERMATOZOÖN

The spermatozoa or male germ-cells are developed in the testes and are present in enormous numbers in the seminal fluid. Each consists of a small but greatly modified cell, and possesses a head, a neck, a connecting piece or body, and a tail (fig. 64).

The **head** is ovoid or elliptical, but flattened, so that when viewed in profile it is pear-shaped. Its anterior two-thirds are covered with a layer of modified protoplasm, named the *head-cap*, which ends anteriorly in a sharp edge. In some animals (e.g. the salamander), the head-cap is prolonged into a barbed spear-like process (*acrosome* or *perforator*), which probably facilitates the entrance of the spermatozoön into the ovum.

* H. von Winiwarter maintains that the number of chromosomes in the immature ovum is forty-eight, and in the primary spermatocyte, forty-seven.

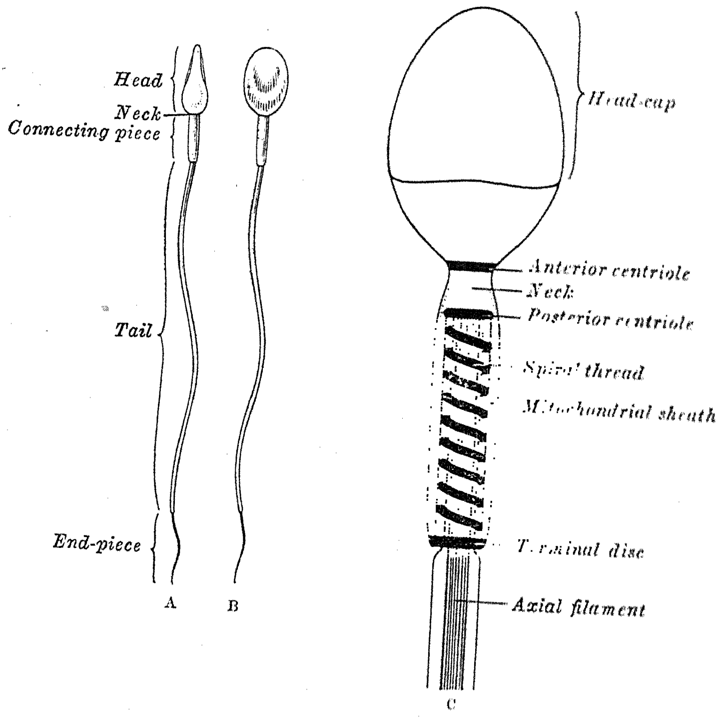
The **neck** is less constricted in the human spermatozoön than in the spermatozoa of some of the lower animals. The *anterior centriole* is situated at the junction of the head and neck, and behind it is a band of homogeneous substance.

The **connecting piece** or **body** is rod-like, and is limited behind by a *terminal disc* or *ring*. The *posterior centriole* is placed at the junction of the body and neck, and from it an *axial filament*, surrounded by a sheath, runs backwards through the body and tail. In the body the sheath of the axial filament is encircled by a *spiral thread*, around which is an envelope containing chondriosomes or mitochondria granules, and termed the *mitochondrial sheath*.

The **tail** consists of the axial thread or filament, surrounded by a thin protoplasmic sheath; the terminal portion or *end-piece* of the tail is composed of the axial filament only.

Krause gives the length of the human spermatozoön as between 52μ and 62μ, the head measuring 4μ to 5μ, the connecting piece 6μ, and the tail from 41μ to 52μ.

FIG. 64.—A human spermatozoa, highly magnified. A. Profile view. B. Surface view. (After Retzius.) C. A diagrammatic representation of the head, neck and connecting piece, more highly magnified. (Modified from Meves.)

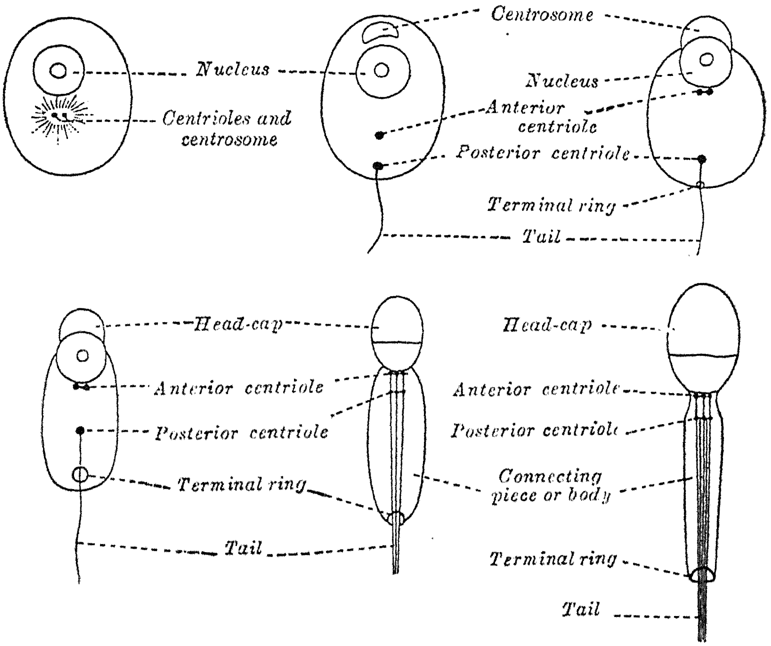


By virtue of their tails, which act as propellers, the spermatozoa are capable of free movement, and if placed in favourable surroundings (e.g. in the female passages) will retain their vitality and fertilising power for several days. In certain animals (e.g. bats) it has been proved that spermatozoa which have been retained in the female passages for several months are capable of fertilising ova.

The spermatozoa are developed from the primary germ-cells imbedded in the testes, and the stages of their development are very similar to those of the maturation of the ovum. The primary germ-cells undergo division and produce a number of cells termed *spermatogonia*, and from these the *primary spermatocytes* are derived. Each primary spermatocyte divides heterotypically into two *secondary spermatocytes*, in the nuclei of which the number of chromosomes is reduced by one-half, and each secondary spermatocyte divides homotypically into two *spermatids* or young spermatozoa; each primary spermatocyte therefore gives rise to *four* spermatozoa.

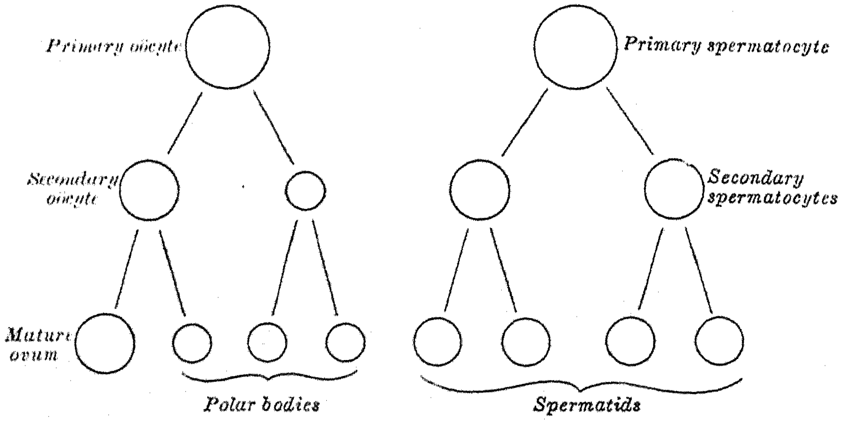
Interesting changes occur during the conversion of the spermatid into the spermatozoön (fig. 65). The two centrioles are at first tangential to the surface of the spermatid but soon assume a radial position so that one lies deeper than the other; the deeper one forms the anterior centriole of the neck. The axial

FIG. 65.—The transformation of a spermatid into a spermatozoön. Diagrammatic. (Modified from Meves.)



filament grows out from the superficial centriole, which divides into two parts; the anterior part forms the posterior centriole of the neck, and the posterior part, which is ring-like, migrates to the distal end of the connecting piece or body and there forms the terminal disc or ring, through which the axial filament passes.

FIG. 66.—A scheme showing the analogies in the process of maturation of the ovum and the development of the spermatids (young spermatozoa).



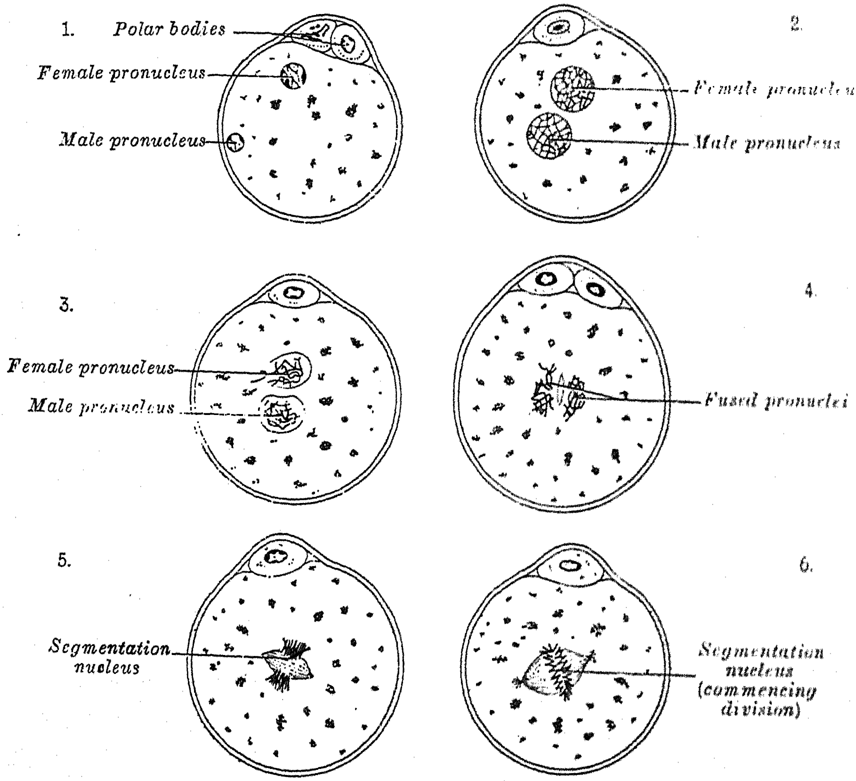
The nucleus of the spermatid forms the head of the spermatozoön, and the cytoplasm, the investing sheath of the body and tail. The centrosome probably moves away from the centrioles to the opposite side of the nucleus and is converted into the head-cap.

On comparing the development of the spermatozoön with the maturation of the ovum (fig. 66) it will be observed that the primary spermatocyte gives rise to two secondary spermatocytes, and the primary oöcyte to the secondary oöcyte and the first polar body ; the two secondary spermatocytes give origin to four spermatozoa, and the secondary oöcyte and first polar body to four cells, the mature ovum and three polar bodies. In the development of the spermatozoön, as in the maturation of the ovum, there is a reduction of the nuclear chromosomes to one-half of those present in the primary spermatocyte. But here the similarity ends, for it must be noted that the four spermatozoa are of equal size, and each is capable of fertilising a mature ovum, whereas the three polar bodies are much smaller than the mature ovum, incapable of further development, and may be regarded as abortive ova.

THE FERTILISATION OF THE OVUM

Fertilisation consists in the union of the spermatozoön with the mature ovum (fig. 67). Nothing is known regarding the fertilisation of the human ovum, but the various stages of the process have been studied in other mammals, and from the knowledge so obtained it is believed that fertilisation of the human ovum takes

FIG. 67.—The process of fertilisation in the ovum of a mouse. (After Sobotta.)

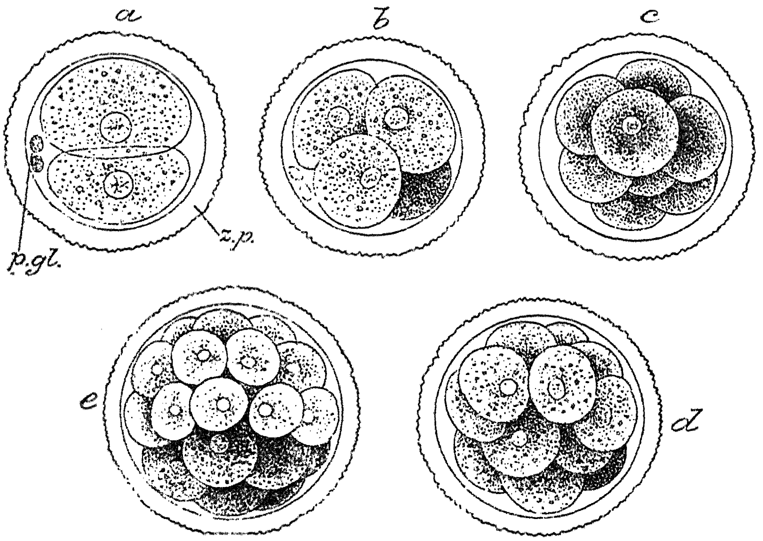


place in the lateral or ampullary part of the uterine tube. The fertilised ovum is then conveyed along the tube to the cavity of the uterus—a journey occupying about seven or eight days ; during the journey the ovum loses its corona radiata and zona striata, and undergoes segmentation. Having pierced the yolk, the spermatozoön loses its tail, while its head and connecting piece assume the form of a nucleus containing a cluster of chromosomes. This constitutes the *male pronucleus*, and associated with it there are a centrosome and centriole. The male pronucleus passes more deeply into the yolk, and the granules of the cytoplasm

surrounding it become radially arranged. The male and female pronuclei migrate towards each other, and, meeting near the centre of the yolk, fuse to form the *first segmentation nucleus* which thus contains both male and female chromatin; the former probably transmits the individualities of the paternal, the latter those of the maternal, ancestors to the future embryo. By the union of the male and female pronuclei the number of chromosomes is restored to that present in the nuclei of the somatic cells.

Applied Anatomy.—Sometimes the fertilised ovum is arrested in the uterine tube, and there undergoes development, giving rise to a *tubal pregnancy*; or it may fall into the abdominal cavity and produce an *abdominal pregnancy*. Occasionally the ovum is not expelled from the Graafian follicle when the latter ruptures, but is fertilised within the follicle and produces what is known as an *ovarian pregnancy*. Under normal conditions only one spermatozoön enters the yolk and takes part in the process of fertilisation. Occasionally a second spermatozoön may enter the yolk, thus giving rise to a condition of *polyspermy*; when this occurs the ovum usually develops in an abnormal manner and gives rise to a monstrosity.

Fig. 68.—The first stages of the segmentation of a mammalian ovum. Semidiagrammatic. (From a drawing by Allen Thomson.) (Quain's Elements of Anatomy.)



z.p. Zona striata. p.gl. Polar bodies. a. Two-cell stage. b. Four-cell stage. c. Eight-cell stage. d, e. Morula stage.

The role of the chromosomes.* According to recent researches the mature ovum contains within itself all the essentials for the formation of a new being, and in the lower forms is capable of producing such when stimulated by mechanical or chemical means. It is interesting to note that the sex of an animal so formed is male. The development of a female necessitates the presence of a spermatozoön containing an additional or specialised chromosome. Thus in some insects the primary oöcyte contains twenty-four chromosomes, and the primary spermatocyte, twenty-three. The mature ovum and the polar bodies each contain twelve chromosomes, while one-half of the spermatozoa contain twelve, and the other half, eleven. If a mature ovum be fertilised by a spermatozoön with eleven chromosomes, the resulting embryo is a male, but if it be fertilised by a spermatozoön with twelve chromosomes, a female embryo is produced. This, however, is not the only factor involved in the determination of sex. The theory advanced is that the chromosomes contain materials which chemically initiate and control the processes that lead to the development of the various tissues and their individual peculiarities. The establishment of a sex-difference is therefore, in the first instance, dependent on a specialised chromosome, but the development of the sexual features results from the presence of specialised chemical substances.

* Consult *The organism as a whole*, by Jacques Loeb, 1916.

THE SEGMENTATION OF THE FERTILISED OVUM

The early segmentation of the human ovum has not yet been seen, but from what is known to occur in other mammals it may be regarded as certain that the process starts immediately after fertilisation, i.e. while the ovum is in the uterine tube. The nucleus exhibits the usual mitotic changes, and these are succeeded by division of the fertilised ovum into two cells of nearly equal size.* The process

FIG. 69.—A section through the blastodermic vesicle of Vespertilio murinus. (After van Beneden.)

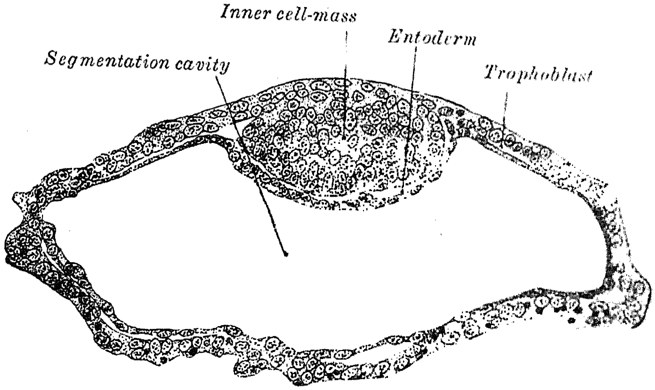


FIG. 70.—A section through the embryonic disc of Vespertilio murinus. (After van Beneden.)

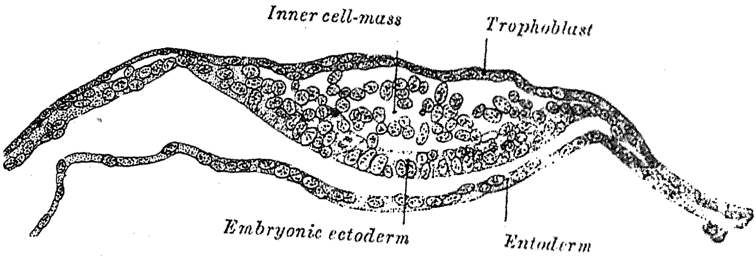
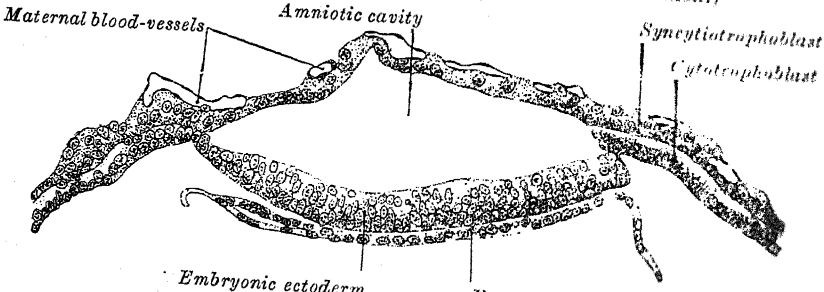


FIG. 71.—A section through the embryonic disc of Vespertilio murinus to show the formation of the amniotic cavity. (After van Beneden.)



* In the mammalian ovum the deuteroplasm is small in amount and uniformly distributed throughout the cytoplasm; such an ovum undergoes *complete* division during the process of segmentation, and is therefore termed *holoblastic*. In the ova of birds, reptiles, and fishes, where the nutritive yolk forms by far the larger portion of the egg, the cleavage is limited to the formative yolk, and is therefore only *partial*; such ova are termed *meroblastic*. Again, it has been observed, in some of the lower animals, that the pronuclei do not fuse but merely lie in apposition. At the commencement of the segmentation process the chromosomes of the two pronuclei group themselves around the equator of the nuclear spindle and then divide; an equal number of male and female chromosomes travel to the opposite poles of the spindle, and thus the male and female pronuclei subscribe equal shares of chromatin to the nuclei of the two cells which result from the subdivision of the fertilised ovum.

is repeated again and again, so that the two cells are succeeded by four, eight, sixteen, thirty-two, and so on, with the result that a mass of cells is found within the zona striata, and to this mass the term *morula* is applied (fig. 68). The cells of the morula, at first closely aggregated, soon arrange themselves into (1) an outer or peripheral layer, the *trophoblast*, which takes no part in the formation of the embryo proper but is concerned in the formation of a protecting membrane, the chorion, from part of which a portion of the placenta is subsequently developed, and (2) an *inner cell-mass*, from a portion of which the embryo is developed. In most mammals fluid collects between the trophoblast and the greater part of the inner cell-mass, and thus the morula is converted into a vesicle which encloses the *segmentation cavity* (fig. 69). The inner cell-mass remains in contact, however, with the trophoblast at one pole of the ovum; this is named the *embryonic pole*, since it indicates the situation where the future embryo is developed. In the human ovum (figs. 72 to 74) there is no actual segmentation cavity but the inner and outer cell-masses are separated in part by delicate strands of mesoderm (magma réticulé or primitive mesoderm). Clefts appear in the magma réticulé, on either side of the developing inner cell-mass, and run together to form the *extra-embryonic cœlom* (fig. 74).

FIG. 72.—A diagram showing the first differentiation of the inner cell-mass.

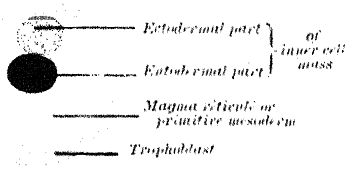


FIG. 73.—A diagram showing the early stages in the formation of the amnion and archenteron.

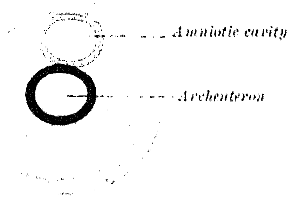
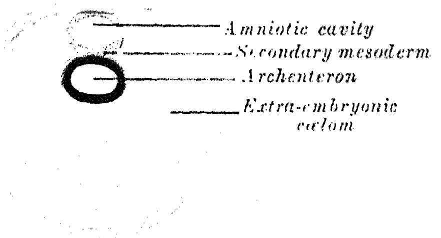


FIG. 74.—A diagram showing the commencing formation of the extra-embryonic cœlom.



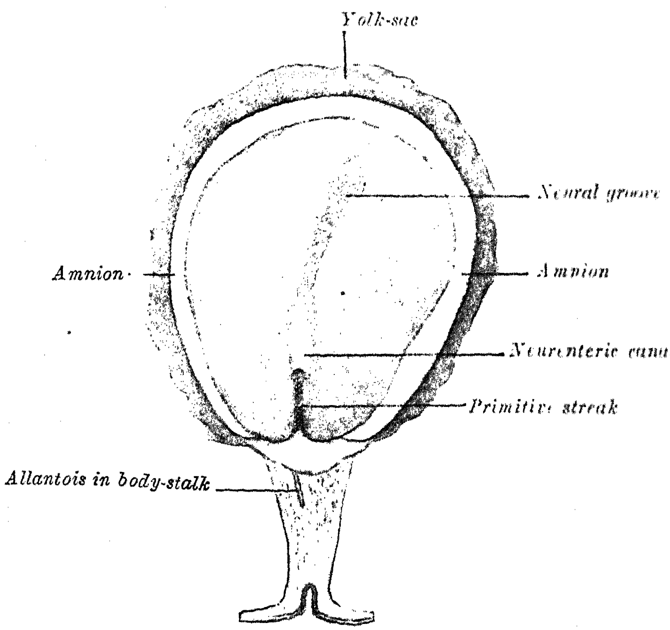
The trophoblast differentiates into two strata: an outer, the *syncytium* or *syncytiotrophoblast*, consisting of a layer of protoplasm studded with nuclei, but showing no evidence of subdivision into cells; and an inner, the *cytotrophoblast* or *layer of Langhans*, in which the cell-outlines are defined. As already stated, the trophoblast takes no share in the formation of the embryo proper; it forms the ectoderm of the chorion and plays an important part in the imbedding of the ovum in the uterine mucous membrane, and in the development of the placenta. The inner cell-mass divides into a dorsal, ectodermal, and a ventral, entodermal, part. Spaces appear between the cells of both parts and coalesce to form cavities; the cavity in the ectodermal part is named the *amniotic cavity*, that in the entodermal part, the *archenteron* (figs. 72, 73). The floor of the amniotic cavity is formed by the *embryonic disc* composed of a layer of prismatic cells, the *embryonic ectoderm*, which is in apposition with the *entoderm* of the archenteron (fig. 71).

The formation of the mesoderm—the primitive streak.—The development of the mesoderm has not been observed in the human ovum, seeing that it is already present in the youngest human ova that have been examined. From what has

been observed in other animals it may be concluded that the primitive streak is its principal source. The embryonic disc becomes oval and then pear-shaped. Near its narrow, caudal end an opaque streak, the *primitive streak* (fig. 75), makes its appearance and extends along the middle of the disc for a considerable part of its length ; at the cephalic end of the streak there is a knob-like thickening of the ectoderm termed *Hensen's knot*. A shallow groove, the *primitive groove*, appears on the surface of the streak, and the cephalic end of this groove communicates with the archenteron through an aperture named the *blastopore*. The primitive streak is produced by a thickening of the axial part of the ectoderm, the cells of which multiply and blend with those of the subjacent entoderm (fig. 76, III, IV, V). From the primitive streak a third layer of cells, the *mesoderm*, extends between the ectoderm and entoderm.

The extension of the mesoderm takes place throughout the whole of the embryonic and extra-embryonic areas of the ovum, except in certain regions. One of these is seen at the cephalic end of the neural tube. Here the mesoderm grows forwards

Fig. 75.—An embryo of Hylobates concolor. Dorsal aspect, with the amnion laid open. (After Selenka.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



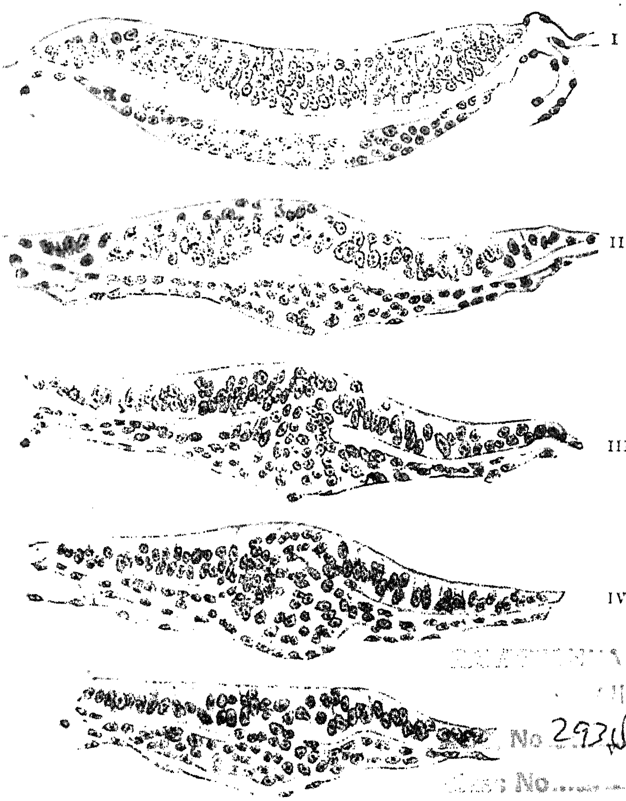
in the form of two crescentic masses, which meet in the middle line so as to enclose an area which is devoid of mesoderm. Over this area the ectoderm and entoderm are in contact with each other and constitute a thin membrane, the *buccopharyngeal membrane*, which forms a septum between the stomodæum or primitive mouth and the fore-gut or head-end of the primitive digestive tube. Where the lateral crescents of mesoderm meet in front of the buccopharyngeal membrane, the pericardium is afterwards developed, and this region is therefore designated the *pericardial area*. At the hind end of the embryo the ectoderm and entoderm are also in contact, and here they form the *cloacal membrane*.

The embryonic disc now consists of three layers, named from without inwards, ectoderm, mesoderm, and entoderm ; each has distinctive characteristics and gives rise to certain tissues of the body.

The **ectoderm** consists of columnar cells, which are, however, somewhat flattened or cubical towards the margin of the embryonic disc. It forms the whole of the nervous system, the epidermis of the skin, the lining cells of the sebaceous, sudoriferous and mammary glands, the hairs and nails, the epithelium of the nose and adjacent air-sinuses, and that of the cheeks and roof of the mouth. From it

also are derived the anterior lobe of the hypophysis cerebri, the epithelium of the cornea, conjunctiva, and lacrimal glands, the neuro-epithelium of the sense-organs, and the enamel of the teeth.

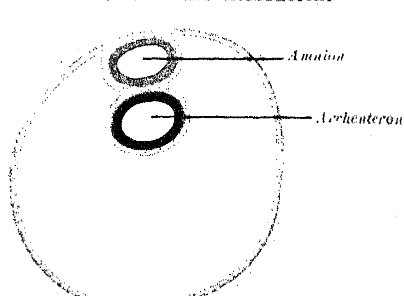
FIG. 76.—A series of transverse sections through the embryonic disc of Tarsius. (After Hubrecht.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



Section I passes through the disc, in front of Hensen's knot, and shows only the ectoderm and entoderm. Sections II, III, and IV pass through Hensen's knot, which is seen in V tapering away into the primitive streak. In III, IV, and V the mesoderm is seen springing from the keel-like thickening of the ectoderm, which in III and IV is observed to be continuous into the entoderm.

The **entoderm** consists at first of flattened cells, which subsequently become columnar. It forms the epithelial lining of the whole of the digestive tube excepting part of the mouth and pharynx and the terminal part of the rectum (which are lined by involutions of the ectoderm), the lining cells of all the glands which open into the digestive tube, including those of the liver and pancreas, the epithelium of the auditory tube and tympanic cavity, of the trachea, bronchi, and air-cells of the lungs, of the urinary bladder and part of the urethra, and that which lines the follicles of the thyreoid gland and thymus.

FIG. 77.—A diagram showing the extension of the mesoderm.



The **mesoderm** consists of loosely arranged branched cells surrounded by a considerable amount of intercellular fluid. From it the remaining tissues of the body are developed. The endothelial lining of the heart and blood-vessels and the blood-corpuscles are, however, regarded by some as being of entodermal origin.

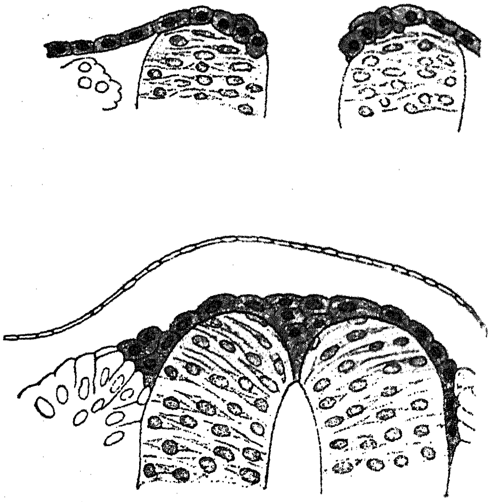
As the mesoderm spreads between the ectoderm and entoderm it is separated for a time into lateral halves by the neural tube and notochord, presently to be

described. A longitudinal groove appears on the dorsal surface of either half and divides it into (*a*) the *paraxial mesoderm* which adjoins the neural tube and notochord, and is subsequently divided into the primitive segments, and (*b*) a lateral portion, the *lateral mesoderm*. The mesoderm in the floor of the longitudinal groove between the paraxial and the lateral mesoderm, is known as the *intermediate cell-mass;* the genito-urinary organs are developed in it, and for this reason it is sometimes named the *nephrogenic cord*. The lateral mesoderm splits into two layers, an outer or *somatic*, which adheres to the outer surface of the ectoderm of the amniotic vesicle, and extends on to the inner surface of the trophoblast now developing into the chorion; and an inner or *splanchnic*, which adheres to the entoderm, and with it forms the *splanchnopleure* (figs. 79, 82). The space between the two layers of the mesoderm is termed the *cœlom*. The intra-embryonic part of the cœlom forms the pericardial, pleural and peritoneal cavities; the extra-embryonic part is obliterated (p. 61).

THE NEURAL GROOVE AND TUBE

Anterior to the cephalic end of the primitive streak two longitudinal ridges, caused by a thickening and upfolding of the ectoderm, make their appearance, one on either side of the middle line (fig. 79). These are named the *neural folds*; they commence near the cephalic end of the embryonic disc, where they are continuous with each other, and gradually extend caudalwards, one on either side of the primitive streak. Between the neural folds is a shallow median groove, the *neural groove* (figs. 79, 80). This groove gradually deepens, and the edges of the folds meet and coalesce in the middle line and convert it into a closed tube, the *neural tube or canal* (fig. 82), the ectodermal wall of which forms the rudiment of the nervous

FIG. 78.—Two stages in the development of the neural crest in the human embryo. (Lenhossék.)



system. By the coalescence of the neural folds over the anterior end of the primitive streak, the blastopore no longer opens on the dorsal surface of the embryo but into the neural tube, and thus a transitory canal, the *neurenteric canal*, is established between the neural and primitive digestive tubes. Closure of the neural groove occurs first in the region of the hind-brain, and from there extends forwards and backwards; towards the end of the third week the anterior opening (*anterior neuropore*) of the tube closes, and forms a recess which is in contact, for a time, with the overlying ectoderm; about the same time the posterior opening or *posterior neuropore* is closed. Subsequently the paraxial mesoderm grows round the neural tube, and separates it from the overlying ectoderm.

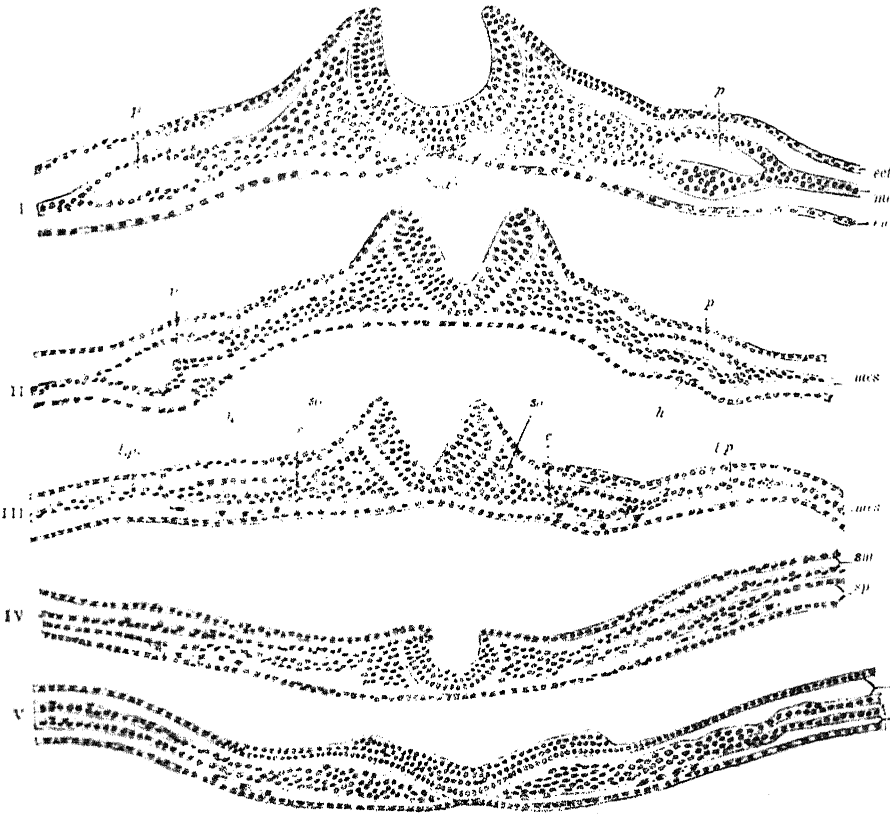
Before the neural groove is closed a ridge of ectodermal cells appears along the margin of either neural fold; this is termed the *neural crest* or *ganglion-ridge* (fig. 78),

and from it the spinal and cerebral nerve-ganglia, the ganglia of the sympathetic nervous system, and the chromaffin bodies are developed.

The cephalic end of the neural groove exhibits several dilatations which, when the neural tube is closed, assume the form of three vesicles; these constitute the three primary cerebral vesicles, and correspond respectively to the future *prosencephalon* (fore-brain), *mesencephalon* (mid-brain), and *rhombencephalon* (hind-brain) (fig. 81). The walls of the vesicles are developed into the nervous tissue and neuroglia of the brain, and the cavities of the vesicles are modified to form the ventricles of the brain. The remainder of the neural tube forms the *medulla spinalis* or *spinal cord*; from its ectodermal wall the nervous and neuroglial elements are formed and its cavity persists as the central canal of the medulla spinalis.

FIG. 79.—A series of transverse sections through the embryo of a dog. (After Bonnet.) (From Quain's Elements of Anatomy, vol. i., Embryology.)

Section I is the most anterior. In V the neural plate is spread out nearly flat. The series shows the uprising of the neural folds to form the neural canal.



a, aorta; *c*, intermediate cell-mass; *ect*, ectoderm; *ent*, entoderm; *h*, *h*, rudiments of endothelial heart tubes. In III, IV, and V the scattered cells represented between the entoderm and splanchnic layer of mesoderm are the vasoformative cells which give origin in front, according to Bonnet, to the heart tubes *h*; *l.p.*, lateral plate still undivided in I, II, and III; in IV and V split into somatic (*sm*) and splanchnic (*sp*) layers of mesoderm; *mes*, mesoderm; *p*, pericardium; *so*, primitive segment.

THE NOTOCHORD

The **notochord** (fig. 82) constitutes the foundation of the axial skeleton, since around it the segments of the vertebral column are formed; its appearance synchronises with that of the neural tube. It grows forwards as a rod of cells (probably of mesodermal origin) from the cephalic end of the primitive streak, and is at first intimately connected with the entoderm underlying the neural groove. It soon separates from the entoderm, and the separation is later emphasised by the meso-

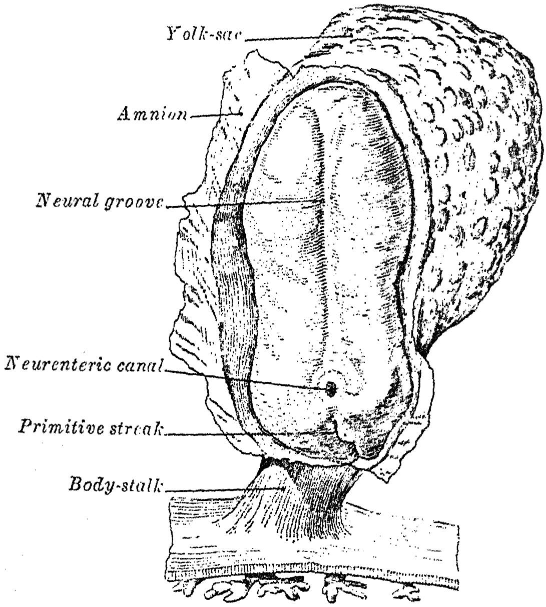
derm which grows medialwards and surrounds it. When fully formed the notochord extends throughout the length of the future vertebral column, and its cephalic end reaches as far as the anterior part of the mid-brain, where it ends in a hook-like extremity in the region of the future dorsum sellæ of the sphenoidal bone. From the mesoderm surrounding the neural tube and notochord, the skull, the vertebral column, and the membranes of the brain and medulla spinalis are developed.

THE PRIMITIVE SEGMENTS

Towards the end of the third week transverse segmentation of the paraxial mesoderm begins, and converts it into a series of well-defined, more or less cubical masses, the *primitive segments* (figs. 81, 82, 83), which extend from the occipital region of the skull along the entire length of the trunk on either side of the middle line. Each segment originally contains a central cavity (*myocœl*), but this is soon filled with angular and spindle-shaped cells.

The primitive segments lie immediately under the ectoderm on the lateral aspect of the neural tube and notochord, and are connected to the lateral mesoderm by the *intermediate cell-mass*. Those of the trunk are divisible into the following groups,

Fig. 80.—A human embryo, 2 mm. in length. Dorsal aspect, with the amnion laid open. × 30. (After Graf Spee.)



viz.: cervical 8, thoracic 12, lumbar 5, sacral 5, and coccygeal from 8 to 10. Those of the occipital region of the head are usually described as being four in number. In mammals primitive segments of the head can only be recognised in the occipital region, but a study of the lower vertebrates leads to the belief that they are present also in the anterior part of the head, and that altogether nine segments are represented in the head region.

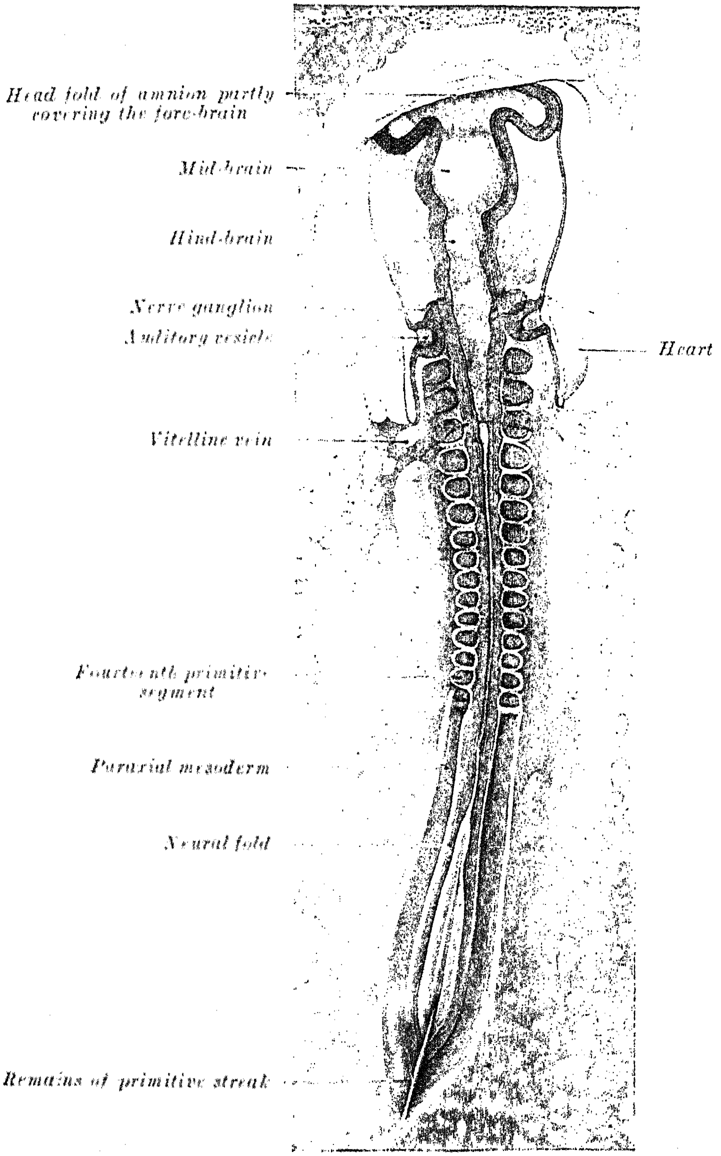
THE FORMATION OF THE EMBRYO

The embryo increases rapidly in size, but the circumference of the embryonic disc, or line of meeting of the embryonic and amniotic parts of the ectoderm, is of relatively slow growth and gradually forms a constriction between the embryo and the greater part of the archenteron. By means of this constriction, which corresponds to the future umbilicus, the dorsal part of the archenteron is enclosed

within the embryo and constitutes the *primitive digestive tube*; the ventral part is left outside the embryo and constitutes the *yolk-sac*.

The embryo grows more rapidly in length than in width, and its cephalic and caudal ends bend in a ventral direction to form the *cephalic and caudal folds* respectively (figs. 89, 90). The cephalic fold is first formed, and the forward growth of

FIG. 81.—A chick embryo thirty-three hours old. Dorsal aspect. × 30. (From Duval's Atlas d'Embryologie.)



the head necessarily carries with it the posterior end of the pericardial area, so that this area and the buccopharyngeal membrane are folded under the head of the embryo. A diverticulum of the archenteron, named the *fore-gut*, is enclosed in the cephalic fold. The caudal end of the embryo is connected to the chorion by a band of mesoderm called the *body-stalk*, but with the continued growth of this end and the formation of the caudal fold the body-stalk assumes a ventral position; a diverticulum of the archenteron extends into the caudal fold and is termed the *hind-gut*. Between the fore-gut and the hind-gut there exists for a time a wide

opening into the yolk-sac, but the relatively slow growth of the latter reduces it to a small pear-shaped sac (sometimes termed the *umbilical vesicle*), and the channel of communication is at the same time elongated to form a narrow tube called the *vitelline duct*.

THE YOLK-SAC

The **yolk-sac** (figs. 84, 85) is situated on the ventral aspect of the embryo; it is lined with entoderm, outside of which is a layer of mesoderm. It is filled with *vitelline fluid*, which is possibly utilised for the nourishment of the embryo during the earlier stages of its existence. Blood is conveyed to the wall of the sac by the ventral branches of the primitive aortæ, and, after circulating through a wide-meshed capillary plexus, is returned by the vitelline veins to the tubular heart of the embryo. By means of this circulation nutritive material is absorbed from the yolk-sac and conveyed to the embryo. At the end of the fourth week the yolk-sac presents the

FIG. 82.—A transverse section through a ferret embryo. (A. Robinson.)

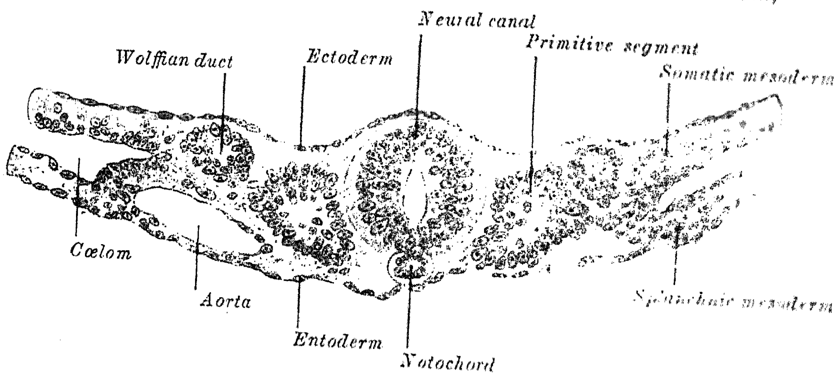
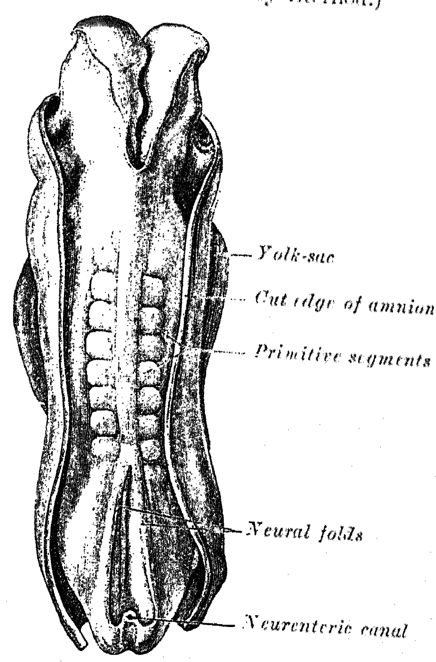


FIG. 83.—A human embryo, 2·1 mm. long. Dorsal aspect. (From a model by Eternod.)



appearance of a small pear-shaped vesicle (umbilical vesicle) opening into the digestive tube by a long narrow tube, the *vitelline duct*. The vitelline duct loses its attachment to the digestive tube, and as a rule undergoes complete obliteration during the seventh week, but in about two per cent. of cases its proximal part persists as a diverticulum (*Meckel's diverticulum*) from the small intestine, situated

FIG. 84.—A sagittal section through the embryo which is represented in fig. 80. (After Graf Spee.)

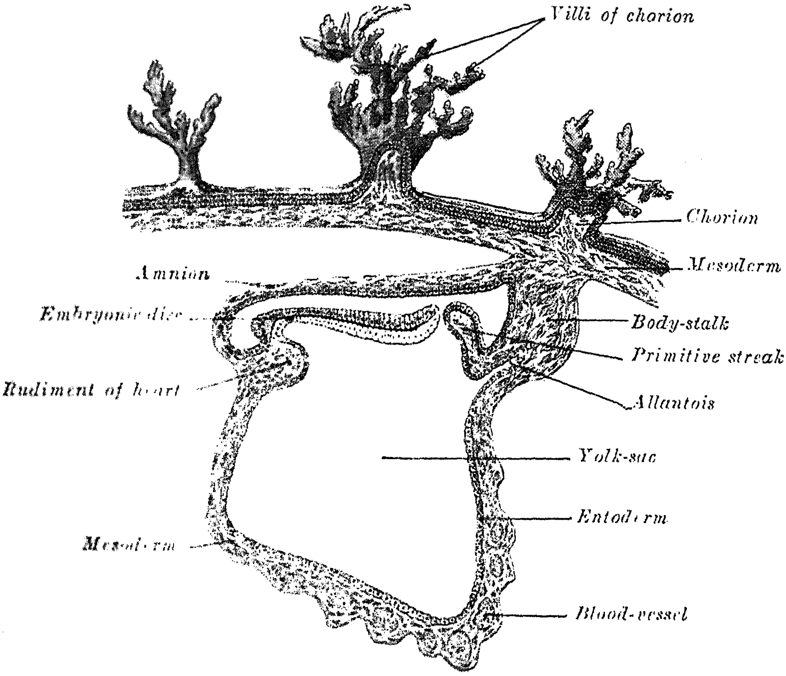
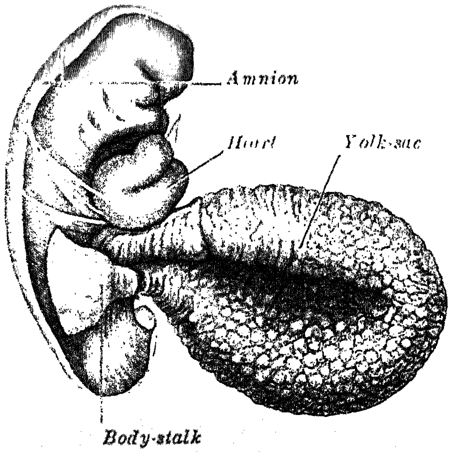


FIG. 85.—A human embryo of 2·6 mm. in length. Lateral aspect. (His.)



about one metre above the ileocolic junction, and sometimes attached by a fibrous cord to the abdominal wall at the umbilicus. A narrowing of the lumen of the ileum is occasionally found opposite the site of attachment of the duct.

The umbilical vesicle can be seen in the after-birth as a small somewhat oval-shaped body with a diameter of from 1 to 5 mm.; it is situated between the amnion and the chorion, and may lie on, or at a variable distance from, the placenta.

THE FŒTAL MEMBRANES AND THE PLACENTA

The **allantois** (figs. 84, 90, 93).—The allantois arises as a tubular diverticulum of the posterior part of the archenteron ; when the hind-gut is developed the allantois is carried backwards with it, and then opens from the cloaca or terminal part of

FIG. 86.—A fœtus of about eight weeks, enclosed in the amnion. Magnified a little over 2 diameters. Drawn from stereoscopic photographs lent by Prof. A. Thomson, Oxford.

the hind-gut : it extends into the mesoderm of the body-stalk which connects the tail-end of the embryo with the chorion. The allantoic diverticulum is lined with entoderm and covered with mesoderm, and in the latter are umbilical vessels.*

* In reptiles, birds, and many mammals the allantois expands into a vesicle which projects into the extra-embryonic cœlom. If its further development be traced in the bird, it is seen to project to the right side of the embryo, and, gradually expanding, spreads over the dorsal surface of the embryo as a flattened sac between the amnion and the serosa (p. 60*), and ultimately surrounds the yolk. Its outer wall becomes applied to, and fuses with, the serosa which lies immediately inside the shell membrane. Blood is carried to the allantoic sac by the two allantoic or umbilical arteries, which are continuous with the primitive aortæ, and after circulating through the allantoic capillaries, is returned to the primitive heart by the two umbilical veins. In this way the allantoic circulation, which is of the utmost importance in connexion with the respiration and nutrition of the chick, is established. Oxygen is taken from, and carbonic acid is given up to the atmosphere through the egg-shell, and nutritive materials are at the same time absorbed by the blood from the yolk. With the formation of the amnion the embryo is, in most animals, entirely separated from the chorion, and is only again united to the chorion when the allantoic mesoderm spreads over and becomes applied to its inner surface ; but the human embryo, as was pointed out by His, is never wholly separated from the chorion, its tail-end being from the first connected with the chorion by means of a thick band of mesoderm, named the *body-stalk*.

Fig. 87.—A diagram showing the earliest observed stage of the human ovum.

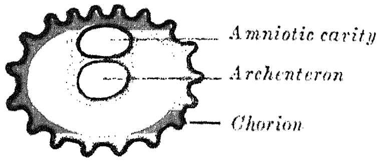


Fig. 88.—A diagram illustrating the early formation of the allantois, and the differentiation of the body-stalk.

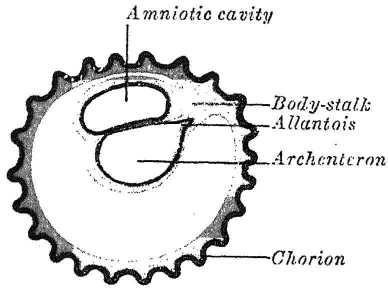


Fig. 89.—A diagram showing a later stage of the development of the allantois.

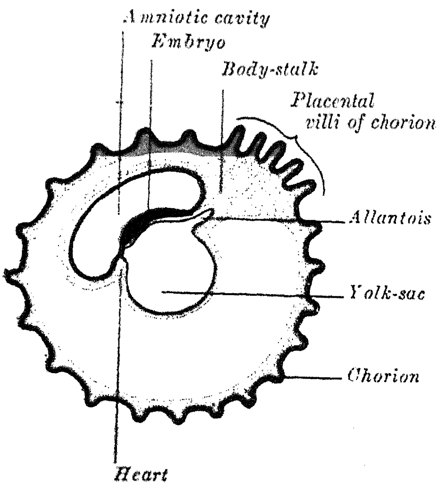


Fig. 90.—A diagram showing the expansion of the amnion, and the delimitation of the umbilicus.

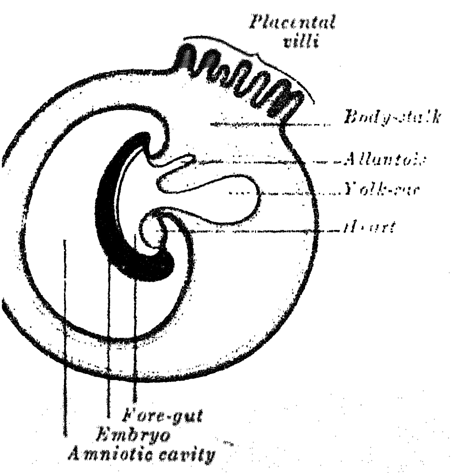
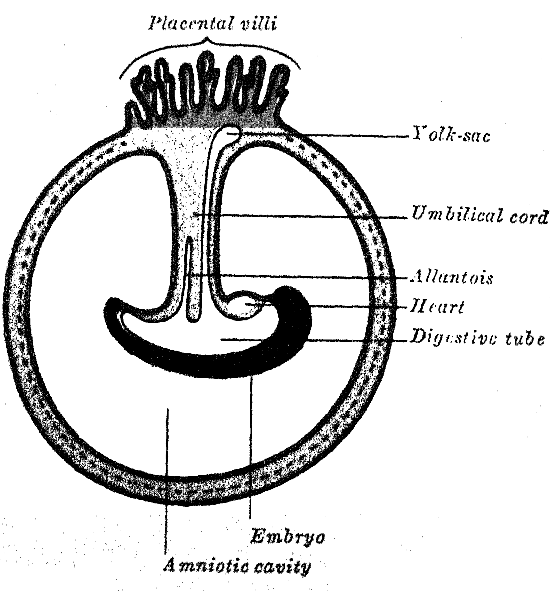


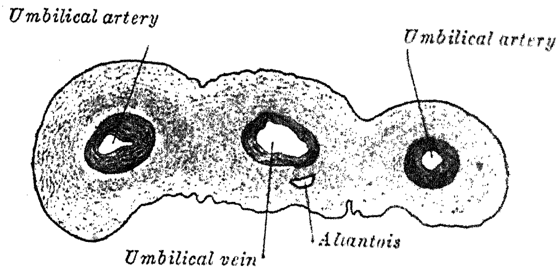
Fig. 91.—A diagram illustrating a later stage in the development of the umbilical cord.



The **amnion** is a membranous sac which surrounds and protects the embryo; it is developed in reptiles, birds, and mammals, but not in amphibia or fishes.

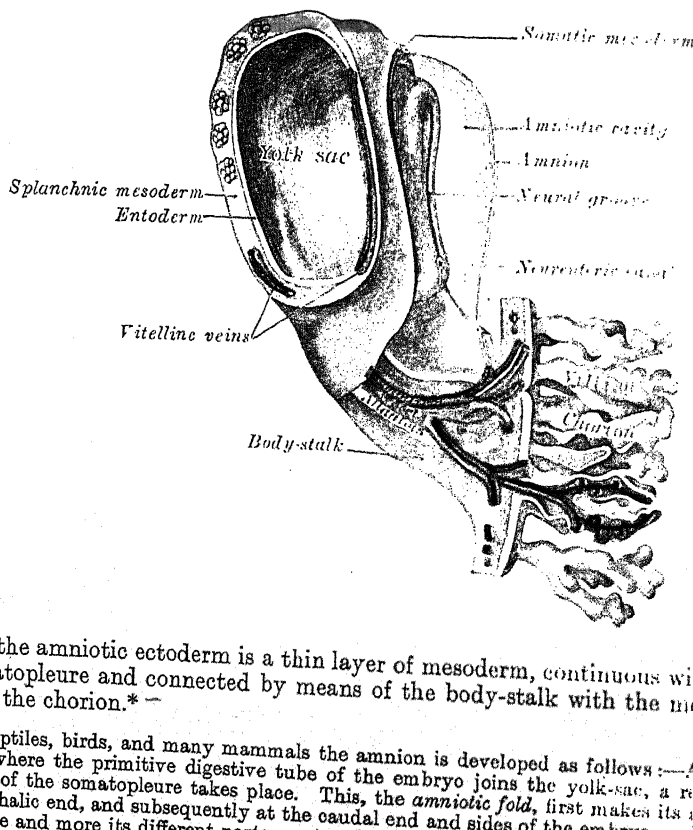
In the human embryo the earliest stages of the formation of the amnion have not been observed; in the youngest embryo which has been studied the amnion was

FIG. 92.—A transverse section through the umbilical cord.



already present as a closed sac (figs. 87, 94), and, as indicated on page 49, appears as a cavity in the ectodermal part of the inner cell-mass. This cavity is roofed in by a stratum of flattened ectodermal cells, the *amniotic ectoderm*, and its floor consists of the prismatic ectoderm of the embryonic disc—the continuity between the roof and floor being established at the margin of the embryonic disc.

FIG. 93.—A human embryo, 1·3 mm. long. (From a model by Eternod.)

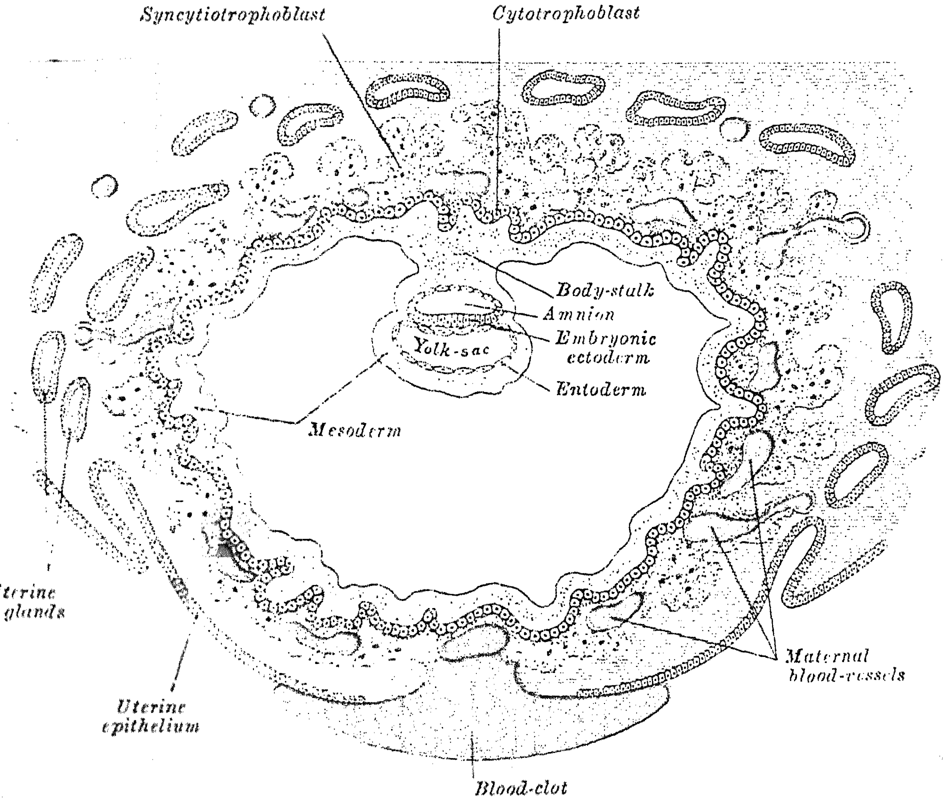


Outside the amniotic ectoderm is a thin layer of mesoderm, continuous with that of the somatopleure and connected by means of the body-stalk with the mesodermal lining of the chorion.*

* In reptiles, birds, and many mammals the amnion is developed as follows:—At the constriction where the primitive digestive tube of the embryo joins the yolk-sac, a reflection or upfolding of the somatopleure takes place. This, the *amniotic fold*, first makes its appearance at the cephalic end, and subsequently at the caudal end and sides of the embryo, and gradually rising more and more its different parts meet and fuse over the dorsal surface of the embryo, and enclose a cavity, the *amniotic cavity*. After the fusion of the edges of the amniotic fold, the two layers of the fold separate; the inner forms the *amnion*, the outer, the *false amnion* or *serosa*. The space between the amnion and the serosa constitutes the extra-embryonic cœlom, and for a time communicates with the embryonic cœlom.

Fluid, termed *liquor amnii*, appears within the amniotic cavity and increases steadily in amount, so that the sac gradually expands and encroaches on the cavity of the extra-embryonic cœlom; this expansion continues until the extra-embryonic cœlom is obliterated. The liquor amnii increases in quantity up to the sixth or seventh month of pregnancy, and then diminishes somewhat; at the end of pregnancy it amounts to about 1 litre. It allows of the free movements of the fœtus during the later stages of pregnancy, and also diminishes the risk to the fœtus of injury from without. It contains less than two per cent. of solids, consisting of urea and other extractives, inorganic salts, a small amount of protein, and frequently a trace of sugar.

Fig. 94.—A section through an ovum imbedded in the uterine decidua. Semidiagrammatic. (After Hubert Peters.)

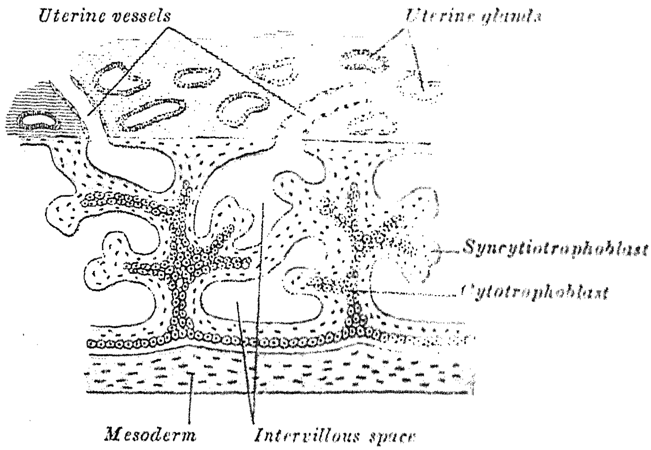


The **body-stalk** and the **umbilical cord.**—The body-stalk (figs. 84, 89, 90, 93) is a band of mesoderm which first connects the tail-end of the embryo with the chorion. Extending into the proximal part of it is the canal of the allantois, and running through it from the embryo to the chorion are the umbilical vessels. Its dorsal surface is covered with the amnion and its ventral surface is bounded by the extra-embryonic cœlom. As a result of the folding of the embryo and the distension of the amnion the body-stalk comes to lie on the ventral surface of the embryo, and its mesoderm approaches that of the yolk-sac and vitelline duct (fig. 90). As a consequence of the continued expansion of the amnion, the extra-embryonic cœlom is obliterated (figs. 90, 91), the vitelline duct is elongated, and the mesoderm of the amnion blends with that of the vitelline duct and body-stalk; by this fusion a solid cord, the *umbilical cord*, is formed (fig. 91) and connects the embryo to that portion of the chorion which will form the fœtal part of the placenta.

The umbilical cord (figs. 92, 100) is enveloped by the amniotic ectoderm and consists of a core of gelatinous tissue (*jelly of Wharton*) in which the umbilical vessels, the allantoic diverticulum, and the vitelline duct and vessels are imbedded. The allantoic diverticulum and the vitelline duct and vessels undergo obliteration

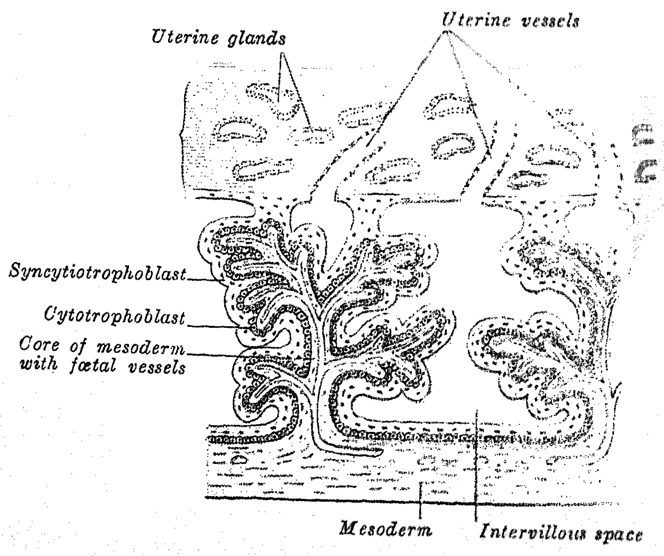
and atrophy, but traces of them may be seen up to the fourth month of pregnancy or later. The umbilical cord becomes spirally twisted, owing, it is believed, to the unequal growth of the two umbilical arteries; it also increases in length so that at the end of pregnancy it is about 50 cm. long.

FIG. 95.—Primary chorionic villi. Diagrammatic. (Modified from Bryce.)



The **implantation or imbedding of the fertilised ovum in the uterine wall.** As already stated (p. 46), fertilisation of the ovum is believed to occur in the lateral or ampullary end of the uterine tube, and is immediately followed by segmentation. The segmenting ovum is conveyed along the uterine tube to the cavity of the uterus,

FIG. 96.—Secondary chorionic villi. Diagrammatic. (Modified from Bryce.)



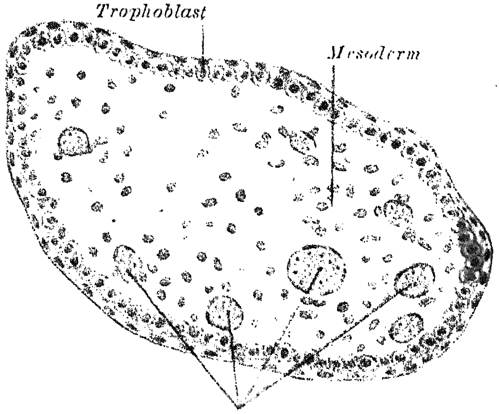
the journey occupying seven or eight days. By the time it reaches the uterus it possesses a well-developed trophoblast. The ovum adheres like a parasite to the uterine mucous membrane, destroys the epithelium over the area of contact, and excavates for itself a cavity in the mucous membrane in which it becomes imbedded. In an ovum described by Bryce and Teacher * the point of entrance of the ovum into

* Contribution to the study of the early development and imbedding of the human ovum, 1908.

the uterine mucous membrane was visible as a small gap closed by a mass of fibrin and leucocytes; in an ovum described by Peters * the opening was covered with a mushroom-shaped mass of fibrin and blood-clot (fig. 94), the narrow stalk of which plugged the aperture in the mucous membrane. Soon, however, all trace of the opening is lost, and the ovum is then completely surrounded by the uterine mucous membrane.

The structure actively concerned in excavating the uterine mucous membrane is the trophoblast. This increases rapidly in thickness, invades and digests the uterine tissues, destroys the epithelial cells of the uterine glands and the walls of the uterine (maternal) blood-vessels (fig. 94); at the same time there appear in the trophoblast numerous anastomosing spaces which are filled with maternal blood. These spaces expand to form what is ultimately known as the *intervillous space*, and the trophoblast is separated into a number of branching processes named the

FIG. 97.—A transverse section of a secondary chorionic villus.



primary chorionic villi (fig. 95) which are bathed in the maternal blood. Cores of mesoderm, containing branches of the umbilical vessels, soon invade the primary chorionic villi and convert them into *secondary chorionic villi* (figs. 96, 97).

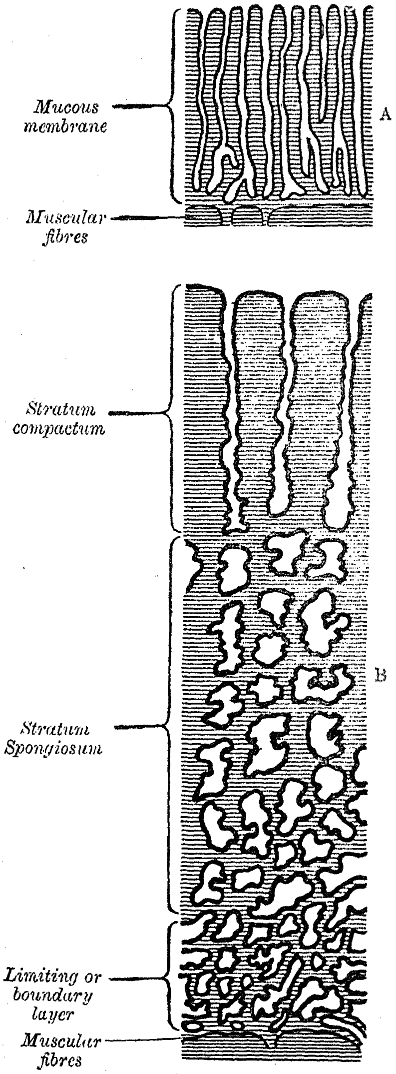
The **decidua.**—Before the fertilised ovum reaches the uterus, the mucous membrane of the body of the uterus undergoes important changes, and is then known as the *decidua*. The thickness and vascularity of the mucous membrane are greatly increased; its glands are elongated and open on its free surface by funnel-shaped orifices, while the deeper portions of the glands are tortuous and dilated into irregular spaces. The interglandular tissue is also increased in quantity, and is crowded with large round, oval, or polygonal cells, termed *decidual cells*. These changes are well advanced by the second month of pregnancy, when the mucous membrane consists of the following strata (fig. 98): (1) *stratum compactum*, next the free surface; in this the uterine glands are only slightly expanded, and are lined by columnar cells; (2) *stratum spongiosum*, where the uterine glands are greatly dilated and very tortuous, and are ultimately separated from one another by a small amount of interglandular tissue; for a time the cells lining the glands are cylindrical, but later they become flattened; (3) a thin *limiting or boundary layer*, next the uterine muscular fibres, containing the deepest parts of the uterine glands, which are not dilated, and are lined with cubical epithelium; it is from this epithelium that the epithelial lining of the uterus is regenerated after parturition.

After the ovum is imbedded distinctive names are applied to different portions of the decidua. The part which covers the ovum is named the *decidua capsularis*; the portion between the ovum and the uterine muscular wall is named the *decidua basalis* or *decidua placentalis*, since it is here that the placenta is subsequently developed; the part which lines the remainder of the body of the uterus is known as the *decidua vera* or *decidua parietalis* (fig. 99).

* *Die Einbettung des menschlichen Eies*, 1899.

Coincidently with the growth of the embryo, the decidua capsularis is thinned and distended (fig. 99) and the space between it and the decidua vera is gradually obliterated. By the beginning of the third month of pregnancy the decidua capsularis and decidua vera are in contact; by the fifth month of pregnancy the decidua capsularis has practically disappeared, while during the succeeding months the decidua vera also atrophies, owing to the increased pressure. The glands of the stratum compactum are obliterated, and their epithelium is lost; in the stratum spongiosum the glands are compressed and appear as slit-like fissures, and their epithelium undergoes degeneration; in the limiting or boundary layer, however, the glandular epithelium retains a cubical form.

Fig. 98.—Sections of the uterine mucous membrane; (A) of the non-pregnant uterus; (B) of the pregnant uterus. Diagrammatic. (Kundrat and Engelmann.)



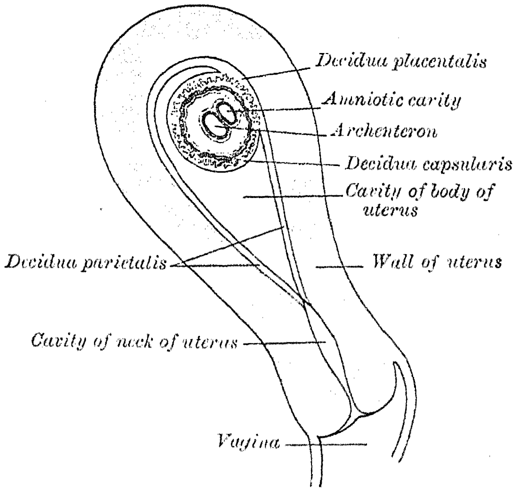
The **chorion** (figs. 89 to 93 and 95 to 97) consists of two layers: an outer of trophoblast, and an inner of mesoderm. The trophoblast consists of an internal layer, the *cytotrophoblast* or *layer of Langhans*, and an external layer, the *syncytiotrophoblast*. As stated (p. 63) the trophoblast undergoes rapid proliferation and forms, on the surface of the chorion, numerous processes, the *primary chorionic villi* (fig. 95); these increase in size and ramify, and the chorionic mesoderm, carrying branches of the umbilical vessels, grows into them, and in this way they are converted into *secondary chorionic villi* (fig. 96). Blood is carried from the embryo to the chorion by the umbilical arteries, and after circulating through the capillaries of the chorionic villi, is returned to the embryo by the umbilical veins. Until about the end of the second month of pregnancy the entire chorion is covered by villi which are almost uniform in size, and project into the decidua placentalis and decidua capsularis (fig. 100). With the growth of the embryo and the expansion of the amniotic cavity the decidua capsularis is thinned and compressed, the circulation through it is gradually cut off, and the villi of the corresponding part of the chorion atrophy and disappear. This portion of the chorion becomes smooth (*chorion læve*); and, as it takes no share in the formation of the placenta, is sometimes named the non-placental part of the chorion. On the other hand, the villi on that part of the chorion which is in contact with the decidua placentalis increase greatly in size and complexity, and hence this part is named the *chorion frondosum* (figs. 90, 91).

The **placenta** (figs. 100 to 102) connects the fœtus to the uterine wall, and is the organ by means of which the nutritive, respiratory, and excretory functions of the fœtus are carried on. It is composed of fœtal and maternal parts.

The *fœtal portion of the placenta* consists of the villi of the chorion frondosum which branches repeatedly, and increase enormously in size. The ends of some of the villi are anchored by columns of trophoblast to the walls of the intervillous space, but the majority hang free in this space. All are bathed in maternal blood, which is conveyed to and from the intervillous space by the uterine vessels. Blood is carried from the embryo to the placental villi by the umbilical arteries, and returned

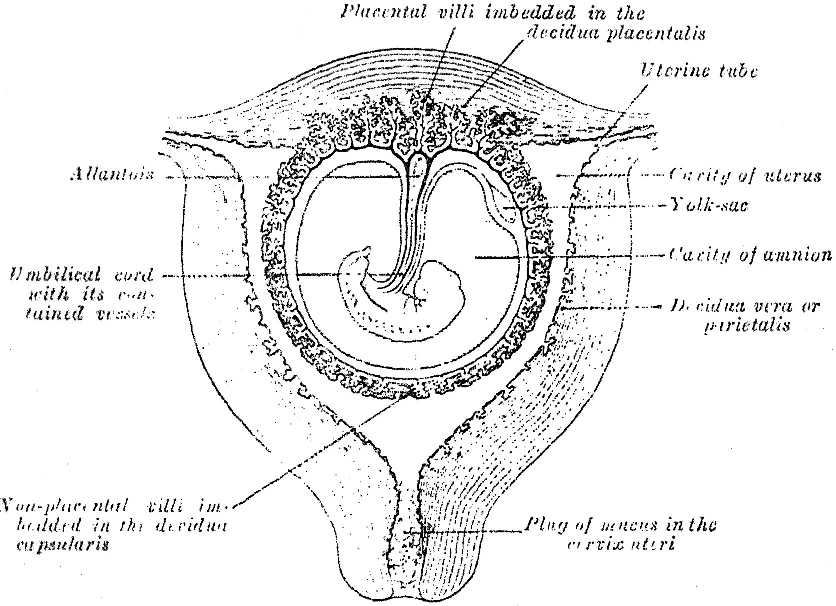
to the embryo by the umbilical veins. One or two branches of an artery enter each villus and there end in a capillary plexus which is drained by one or two tributaries of the veins. The vessels of the villi are surrounded by a thin layer of mesoderm which is covered with the two strata of the trophoblast, the cytotrophoblast or layer of Langhans being in contact with the mesoderm, and the syncytiotrophoblast in contact with the maternal blood (fig. 102); after the fifth month the two strata are replaced by a single layer of somewhat flattened cells.

FIG. 99.—Diagram showing the ovum imbedded in the uterine decidua.



The *maternal portion of the placenta* is formed by the decidua placentalis containing the intervillous space. As already explained (p. 63), this space is produced by the enlargement and intercommunication of the spaces in the trophoblast; it is therefore lined throughout with syncytiotrophoblast. The formation of the intervillous space involves the disappearance of the greater portion of the stratum compactum, but the deeper part of this layer persists and is condensed to form what is known as the *basal plate*; this constitutes the outer wall of the intervillous space, and consists of a stroma containing decidual cells, portions of trophoblast and *fibrinoid substance*; the last appears to be derived in part from the trophoblast and in part from the maternal blood. Between the basal plate and the uterine muscular fibres are the stratum spongiosum and the limiting layer; through these and the basal plate the uterine arteries and veins pass to and from the intervillous space. Portions of the stratum compactum persist as pillars which project into

FIG. 100.—A sectional plan of the gravid uterus in the third month. (Modified from Wagner.)



manipulation and pressure causing the oily matter to collect into drops; in consequence of the extreme delicacy of the primitive sheath even slight pressure will cause the transudation of the fatty matter, which collects as drops of oil outside the sheath.

The *neurolemma* or *primitive sheath* is a delicate, structureless membrane; here and there beneath it, and situated in depressions in the white substance of Schwann, are nuclei, each surrounded by a small amount of protoplasm. The nuclei are oval and somewhat flattened, and one is generally found in the middle of each internode. The primitive sheath is absent from the medullated fibres of the brain and medulla spinalis.

FIG. 59.—Medullated nerve-fibres stained with silver nitrate.

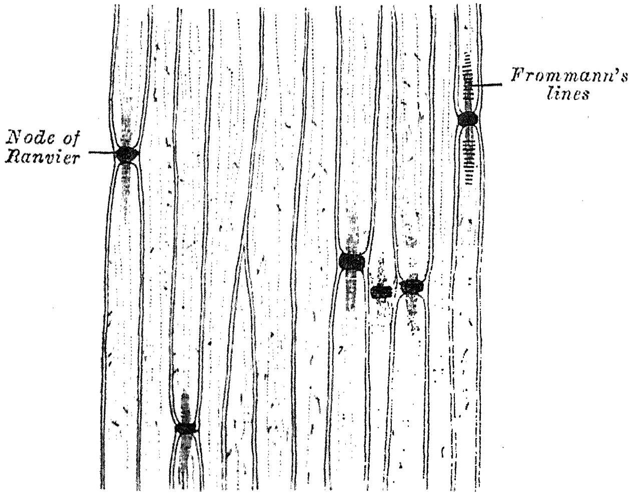
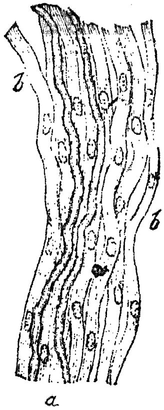


FIG. 60.—A small branch from the sympathetic trunk of a mammal.



a. Two small medullated nerve-fibres among a number of non-medullated nerve-fibres, *b.*

Wallerian Degeneration.—When nerve-fibres are cut across, the central ends of the fibres degenerate as far as the first node of Ranvier; but the peripheral ends degenerate simultaneously throughout their whole length. The medullary sheath of each fibre becomes broken down, forming droplets of fatty substance, and the axon undergoes fragmentation. The nuclei of the primitive sheath proliferate, and finally absorption of the axons and fatty substance occurs. If the cut ends of the nerve be sutured together, regeneration of the nerve-fibres takes place by the downgrowth of axons from the central end of the nerve. At one time it was believed that the regeneration was peripheral in origin, but this has been disproved, the proliferated nuclei in the peripheral portions taking part merely in the formation of the so-called scaffolding along which the new axons pass.

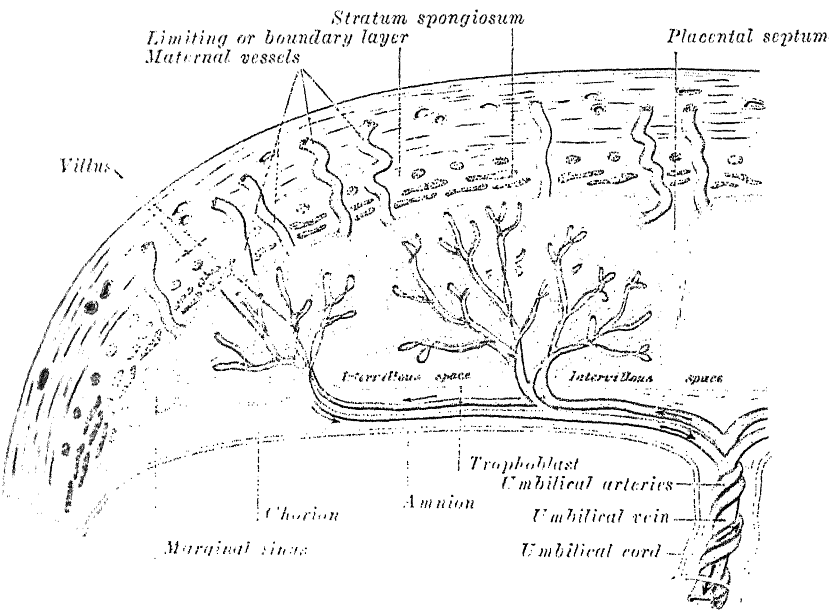
Non-medullated fibres.—Most of the fibres of the sympathetic system, and some of the cerebrospinal, consist of the *grey* or *gelatinous* nerve-fibres (*fibres of Remak*) (fig. 60). Each of these consists of an axis-cylinder to which nuclei are applied at intervals. These nuclei are believed to be in connexion with a delicate sheath corresponding with the neurolemma of the medullated nerve-fibre. In external appearance the non-medullated nerve-fibres are semitransparent and grey or yellowish-grey. The individual fibres vary in size, generally averaging about half the size of the medullated fibres.

level, and in very rare cases occludes the internal orifice of the uterus, thus giving rise to the condition known as *placenta prævia*.

The *separation of the placenta*.—After the child is born, the placenta and membranes (the latter consisting of the amnion, the chorion læve and the superficial part of the decidua parietalis) are separated from the uterine wall and expelled as the *after-birth*. The separation takes place along the plane of the stratum spongiosum (fig. 102), and necessarily causes rupture of the uterine vessels. The orifices of the torn vessels are, however, closed by the firm contraction and retraction of the uterine muscular fibres, and thus *post-partum hæmorrhage* is prevented. After the separation of the placenta and membranes a thin layer of the stratum spongiosum is left as a lining to the uterus, but this layer subsequently undergoes degeneration, and is cast off. The mucous membrane, the glands and the epithelial lining of the uterus are regenerated from the limiting or boundary layer of the decidua (p. 63).

The expelled placenta is a discoid mass which has a weight of about 500 gm., a diameter of from 15 cm. to 20 cm., and an average thickness of about 3 cm., but

Fig. 102.—A scheme of the placental circulation.



the thickness rapidly diminishes near the circumference of the placenta, which is continuous with the membranes. Its uterine or outer surface is divided by a series of fissures into lobules or *cotyledons* which are imperfectly separated from one another by the placental septa. Its fœtal or inner surface is smooth, and is closely invested by the amnion. When looked at through the amnion, the chorion presents a mottled appearance, consisting of grey, purple, or yellowish areas. The umbilical cord is usually attached near the centre of the placenta, but may be inserted at any point between the centre and the margin; in some cases it is inserted into the membranes, i.e. the *velamentous* insertion. From the site of the attachment of the cord the larger branches of the umbilical vessels radiate under the amnion, the veins being deeper and larger than the arteries. The remains of the vitelline duct and yolk-sac may be sometimes observed beneath the amnion, close to the cord, the former as an attenuated thread, the latter as a minute sac.

On section, the placenta presents a soft, spongy appearance, caused by the greatly branched villi; these are surrounded by a varying amount of maternal blood which gives the dark red colour to the placenta.

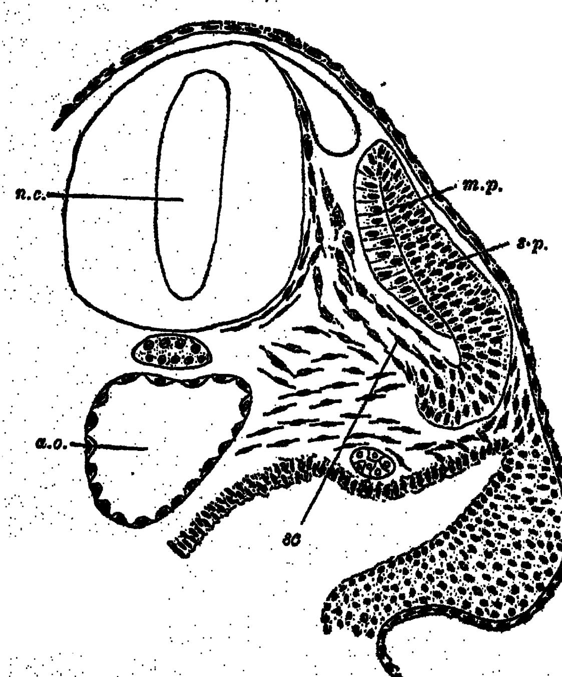
The further growth of the embryo will be best understood from a description of the principal facts relating to the development of the chief systems of which the body consists.

THE DEVELOPMENT OF THE PARIETES

The **skeleton** is of mesodermal origin, and may be divided into (1) the axial skeleton, viz. that of the vertebral column, skull, ribs, and sternum, and (2) the appendicular skeleton, viz. that of the limbs.

The vertebral column.—The notochord (fig. 82) is a temporary structure and forms a central axis, around which the segments of the vertebral column are developed.* The notochord is derived from the cephalic end of the primitive streak, and, when fully formed, consists of a rod of cells, which lies on the ventral aspect of the neural tube and reaches from the anterior end of the mid-brain to the extremity of the tail. On either side of it is a column of paraxial mesoderm which becomes subdivided into a number of more or less cubical segments, the *primitive segments* (figs. 81, 83). These are separated from one another by *inter-segmental septa* and are arranged symmetrically on either side of the neural tube and notochord: to each primitive segment a spinal nerve is distributed. At first each segment contains a central cavity, the *myocœl*, but this is soon filled with a core of angular and spindle-shaped cells. The cells of each segment are differentiated into three groups, which form respectively the cutis-plate or dermatome, the muscle-plate or myotome, and the sclerotome (fig. 103). The *cutis-plate* is placed on the lateral and dorsal aspects of the myocœl, and from it the true skin of the corresponding segment is derived; the *muscle-plate* is situated on the medial side of the cutis-plate, and furnishes the muscles of the segment. The cells of the *sclerotome*, largely derived from those forming the core which fills the myocœl, lie next the notochord. Fusion of the individual sclerotomes in an anteroposterior direction soon takes place, and thus a continuous strand of cells, the *scleratogenous layer*, is formed along the ventrolateral aspect of the neural tube. The cells of this layer proliferate rapidly, and extending medialwards surround the notochord; at the same time they grow backwards on the lateral aspects of the neural tube and eventually surround it, and thus the notochord and neural tube are enveloped by a continuous sheath of mesoderm (fig. 105, A), which is termed the *membranous vertebral column*. In this mesoderm the original sclerotomes are still distinguishable, but each is now differentiated into two portions, an anterior, consisting of loosely arranged cells, and a posterior, of more condensed tissue (fig. 104, A and B). Between the two portions the rudiment of the intervertebral fibrocartilage is laid down (fig. 104, C). Cells from the posterior mass grow into the intervals between the myotomes (fig. 104, B and C) of the corresponding and succeeding segments, and extend both dorsally

FIG. 103.—A transverse section of a human embryo of the third week, to show the differentiation of the primitive segment. (Kollmann.)

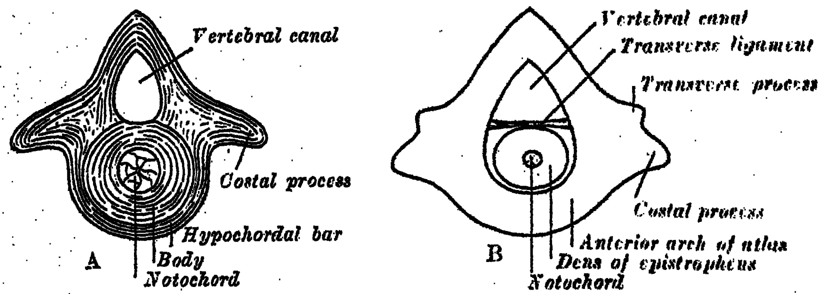


a.o, aorta; *m.p.*, muscle-plate; *n.c.*, neural canal; *sc.*, sclerotome; *s.p.*, cutis-plate.

* In *Amphioxus* the notochord persists and is the only representative of a skeleton in that animal.

cartilage. In the atlas it persists, undergoes chondrification, and develops into the anterior arch of this bone, while the cartilage representing the body of the atlas forms the dens or odontoid process which fuses with the body of the epistropheus or second cervical vertebra (fig. 106, B).

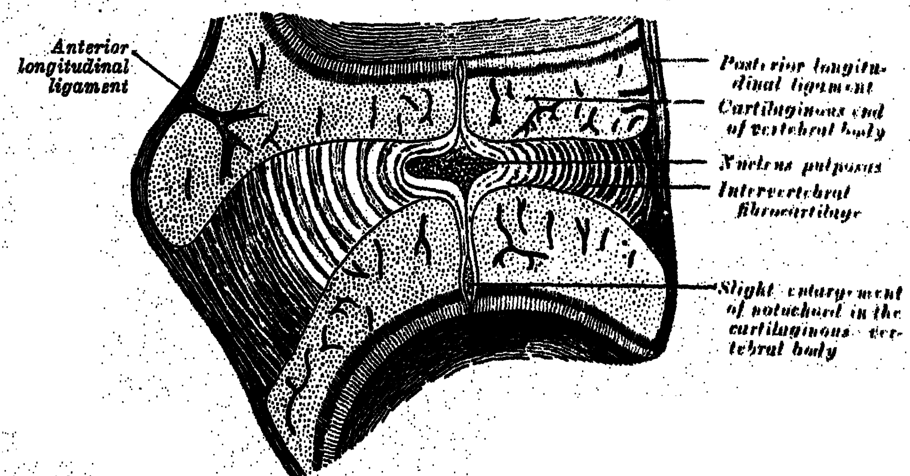
Fig. 106.—Diagrams showing the transformation of the hypochordal bar into the anterior arch of the atlas.



The portions of the notochord contained within the bodies of the vertebræ atrophy, and ultimately disappear, while the portions in the centres of the intervertebral fibrocartilages expand, and persist throughout life as the central *nucleus pulposus* of each fibrocartilage (fig. 107).

The ribs.—The ribs are formed from the costal processes of the primitive vertebral arches, the processes extending between the muscle-plates. In the *thoracic region* of the vertebral column the costal processes grow lateralwards to form a series of arches, the *primitive costal arches.* The transverse process grows out behind the vertebral end of the costal process, and is at first connected to this process by mesoderm which is later differentiated to form the costotransverse ligaments; between the costal process and the tip of the transverse process the costotransverse

Fig. 107.—A sagittal section through an intervertebral fibrocartilage and the adjacent parts of two vertebræ of the embryo of a sheep. (Kölliker.)

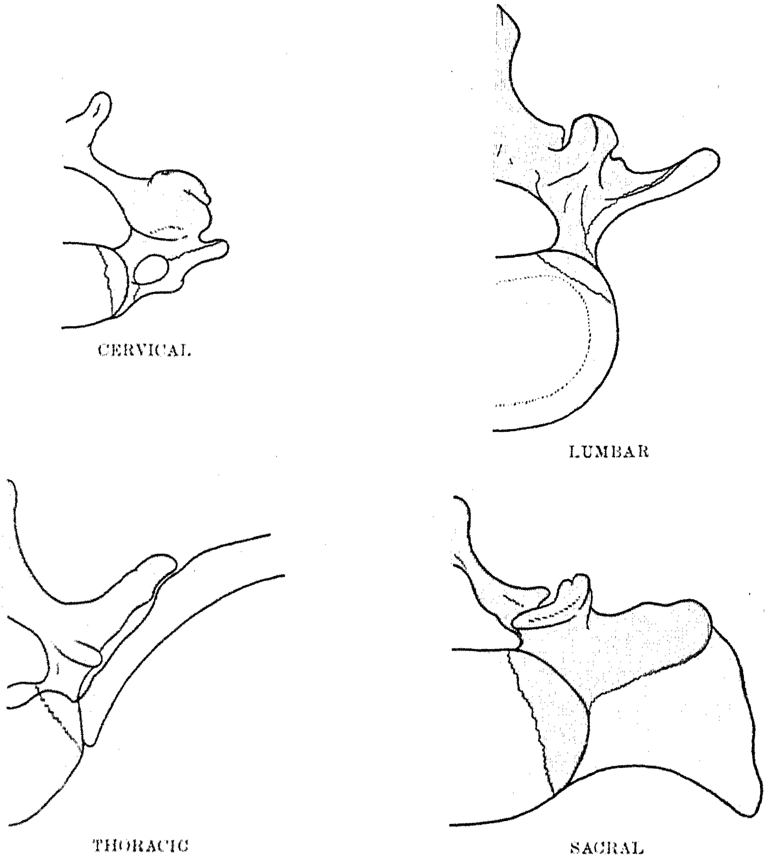


joint is formed by absorption, while the proximal end of the costal process becomes separated from the vertebral arch by the development of the costocentral joint. In the *cervical vertebræ* (fig. 108) the transverse process forms the posterior boundary of the foramen transversarium, while the costal process, corresponding to the head and neck of the rib, remains in continuity with the body of the vertebra, and forms the anterolateral boundary of this foramen. The distal portions of the primitive costal arches remain undeveloped; occasionally, however, the costal processes of the seventh cervical vertebra undergo greater development, and by the formation of costovertebral joints are separated off as cervical ribs. In the *lumbar region* the distal portions of the primitive costal arches fail; the proximal portions fuse with the

transverse processes to form the transverse processes of descriptive anatomy. Occasionally a pair of movable ribs is developed in connexion with the first lumbar vertebra. In the *sacral region* costal processes are developed only in connexion with the upper three or four vertebræ; the processes of adjacent segments fuse with one another to form the lateral parts of the sacrum. The *coccygeal vertebræ* are devoid of costal processes.

FIG. 108.—Diagrams showing the portions of the adult vertebræ derived respectively from the bodies, vertebral arches, and costal processes of the embryonic vertebræ.

The bodies of the vertebræ are represented in yellow, the vertebral arches in red, and the costal processes in blue.



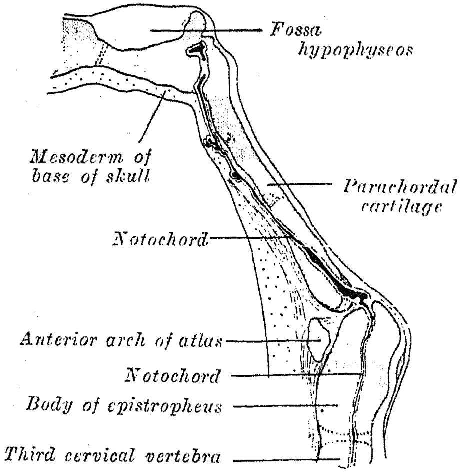
The **sternum.**—The ventral ends of the ribs become united to one another by a longitudinal bar termed the *sternal plate*, and opposite the first seven pairs of ribs these sternal plates fuse in the middle line to form the manubrium and body of the sternum. The xiphoid process is formed by a backward extension of the sternal plates.

The **skull.**—The bones of the cranium are developed from the mesoderm which invests the cerebral vesicles. At the end of the first and beginning of the second month of fœtal life this mesoderm increases in thickness and forms masses of blastema. These masses represent the earliest distinguishable elements of the skeleton of the head, and first become evident in the occipital region where they form a plate, the so-called *occipital plate*; in the middle of this plate the notochord runs sagittally. The occipital plate sends out on either side two processes which surround the hypoglossal nerve and form the hypoglossal canal.

The occipital plate is continued forwards as a thin blastemal layer on the dorsal aspect of the pharynx, and reaches the rudiment of the hypophysis. At the beginning of the second month it surrounds the duct of the hypophysis and extends between the nasal fossæ where it forms the basis of the ethmoidal bone and the nasal septum.

About the fifth week the two auditory vesicles become enclosed in blastemal capsules, each of which is soon differentiated into a dorsolateral part enveloping the semicircular canals, and a ventromedial part surrounding the cochlea; at the upper boundary between these two parts the facial nerve lies in a deep groove. The blastemal auditory capsules fuse with the lateral processes of the occipital plate, leaving, however, a wide gap between each capsule and the more median part of the occipital plate; through this gap the internal jugular vein, and the glossopharyngeal, vagus and accessory cerebral nerves are transmitted.

Fig. 109.—A sagittal section through the cephalic end of the notochord. (Keibel.)



At this stage the blastema which surrounds the hypophysial duct and forms the rudiment of the post-sphenoidal part of the body of the sphenoidal bone, sends out a wing-like process on either side, the future great wing (ala magna). More anteriorly, from the central blastema which is to form the interorbitonasal septum, processes extend laterally and indicate the sites of the small wings (alæ parvæ) of the sphenoidal bone, while condensations occur on either side of the nasal fossæ and blend above with the blastemal septum.

The first indications of the vault of the skull are seen about the thirtieth day, and consist of blastemal plates which appear at the sides of the head and gradually extend into the upper wall where they blend with one another; they also blend with the blastema at the base of the cranium.

In the shark and dogfish this blastemal cranium undergoes complete chondrification and forms the cartilaginous skull or chondrocranium of these animals. In mammals the process of chondrification is limited to the base of the skull, including a region dorsal to the foramen magnum and the auditory capsules. Chondrification takes place primarily in two regions: (*a*) the anterior or *prechordal* part is developed in front of the notochord and shows no regular division into primitive segments; (*b*) the posterior or *chordal* part of the base of the skull is developed from the blastema which surrounds the notochord, and exhibits traces of four primitive segments separated from one another by the roots of the hypoglossal nerve. (In the spring squirrel there is definite evidence that five primitive segments enter into the posterior part, as there are four separate roots of the hypoglossal nerves, and four hypoglossal canals.)

In mammals chondrification takes place primarily in three regions; (*a*) posterior, in relation to the notochord; (*b*) intermediate, in relation to the hypophysis; and (*c*) anterior, between the orbital cavities and the nasal cavities. These parts may be named *chordal, hypophysial,* and *interorbitonasal*; perhaps the last is identical with the trabeculæ cranii of the majority of vertebrates lower than mammals. It is uncertain what the hypophysial part represents; when ossified it forms the postsphenoid.

* In man chondrification of the skull (figs. 110, 111, 112, 113) begins in the second month of fœtal life, even before the blastemal stage is completed, and the first nuclei appear in the occipital plate, one on either side of the notochord, medial to the hypoglossal canal. About the thirty-sixth day these two nuclei fuse anteriorly on the dorsal surface of the notochord, and later they fuse posteriorly on its ventral surface. Thus the notochord lies dorsal to the caudal part of the cartilaginous occipital plate, then traverses the plate and lies ventral to it, and finally passes in front of it and ends on the dorsal surface of the post-sphenoidal cartilage (fig. 109).

The posterior part of the sphenoidal cartilage chondrifies from two centres, one on either side of the developing hypophysis; these unite first behind and then in front of the duct of the hypophysis, and in this way the craniopharyngeal canal,

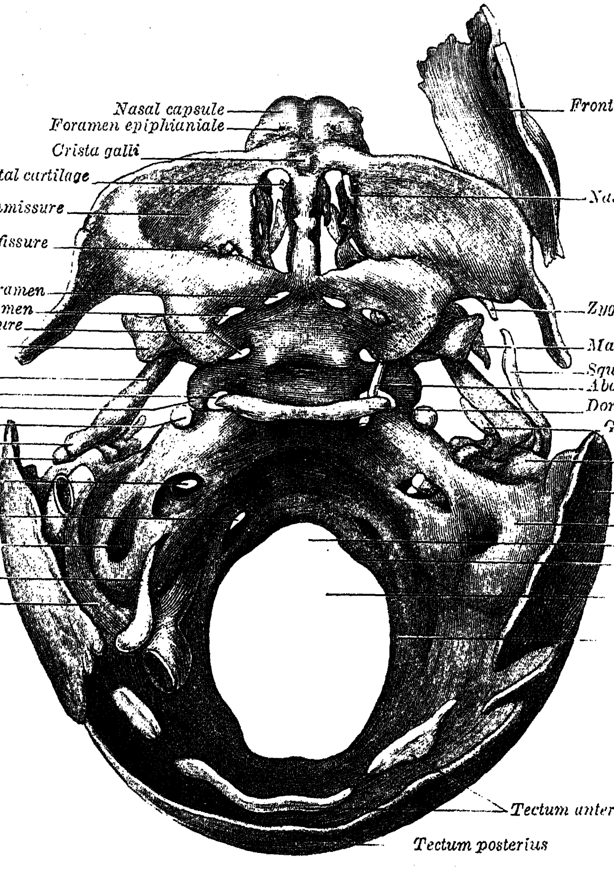
* The following description is mainly based on the researches of Professor E. Fawcett. The reader is referred for further details to the *Journal of Anatomy and Physiology*, volumes xlv., li. and lii., and to the *Proceedings of the Anatomical Society of Great Britain and Ireland*, 1916.

through which the hypophysial diverticulum ascends into the skull, is formed; this canal is usually obliterated at the third month, but may remain open.

The central blastema in front of the hypophysis undergoes independent chondrification; it speedily joins with the posterior end of the chondrifying interorbitonasal septum, and from these are subsequently developed the presphenoidal part of the sphenoidal bone and the bony (ethmoidal) part of the nasal septum. All the above-mentioned parts ultimately fuse and form a continuous cartilaginous stem from the anterior edge of the foramen magnum to the anterior end of the nose.

The blastemal auditory capsule next undergoes chondrification, the portion surrounding the semicircular canals (canalicular portion) chondrifying before that enveloping the cochlea. A plate of cartilage (parietal plate) is connected to the

Fig. 110.—The chondocranium of a human embryo of a crown-rump length of 27 mm. Superior aspect. (From a model prepared by Prof. Edward Fawcett and Gwladys Ruth Llewelyn, B.Sc.)



top of the canalicular part of each auditory capsule by means of a cartilaginous commissure. At the third month this plate forms a considerable part of the side-wall of the cranium, and is separated by only a small interval from the hinder end of the small wing of the sphenoidal bone. The distance between the two rapidly increases as age advances owing to the disappearance of the cartilage.

It is highly probable that the roof of the cranium in its typical human condition is formed by three tecta, which may be called the *tectum posterius*, *tectum intermedium*, and *tectum anterius*. The tectum posterius is broadest from above downwards, and when ossified forms the supra-occipital segment of the occipital bone. The tectum intermedium is very narrow and lies immediately in front of the tectum posterius; it soon disappears, and may not even form. The tectum anterius which stretches between the two parietal plates is a compound structure consisting of two lateral pieces, one on each side, and a median unpaired segment.

FIG. 111.—The chondrocranium shown in fig. 110. Inferior aspect.

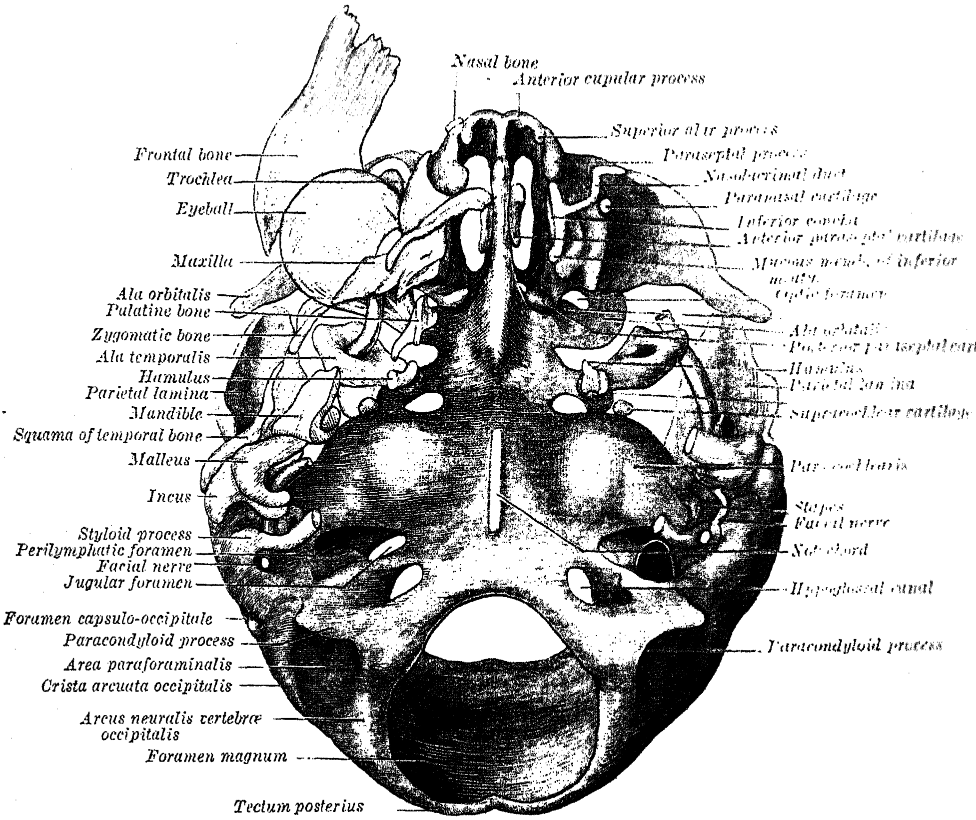
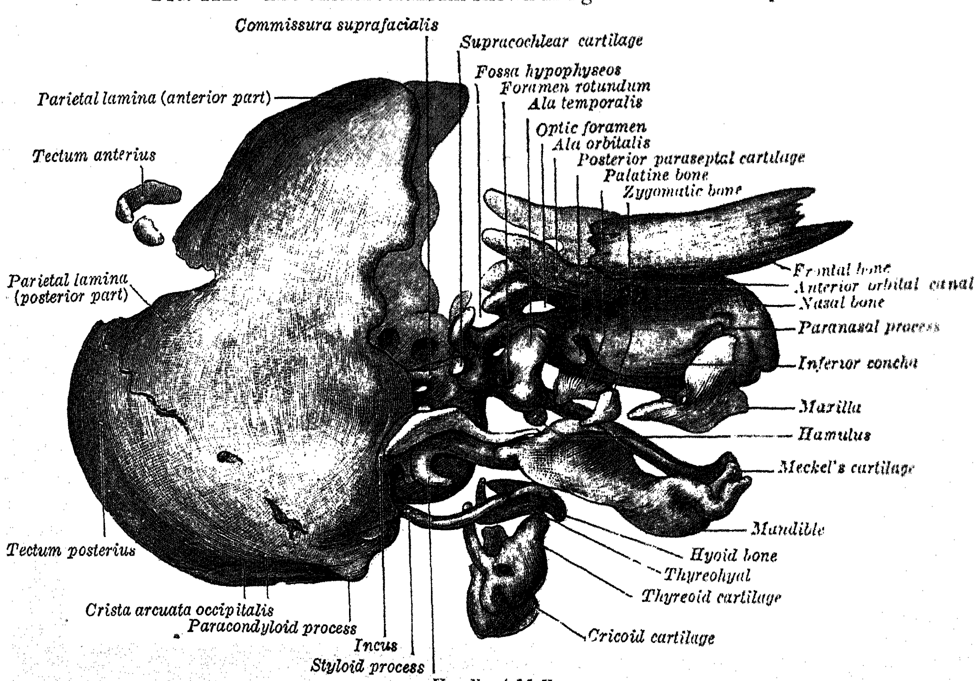


FIG. 112.—The chondrocranium shown in fig. 110. Lateral aspect.



The great wings of the sphenoidal bone have separate cartilaginous nuclei; these fuse with the post-sphenoidal cartilage and with two nuclei which connect

the post-sphenoidal cartilage and the corresponding great wing with the anterior end of the cochlear capsule, lateral to the carotid artery. These nuclei form, on either side, the alar process which later ossifies as the lingula. The cartilaginous great wing is smaller than the small wing and only gives rise to the root of the pterygoid process and to that part of the bone which surrounds the maxillary division of the trigeminal nerve.

Between the great wing and the auditory capsule is a wide space which lodges the semilunar (Gasserian) ganglion and transmits the mandibular division of the trigeminal nerve and the middle meningeal artery. The backward growth of the alar process cuts off this space from the carotid canal, and at a later date the mandibular nerve and middle meningeal artery are surrounded by membrane bone. The space between the great and small wings forms the superior orbital (sphenoidal) fissure.

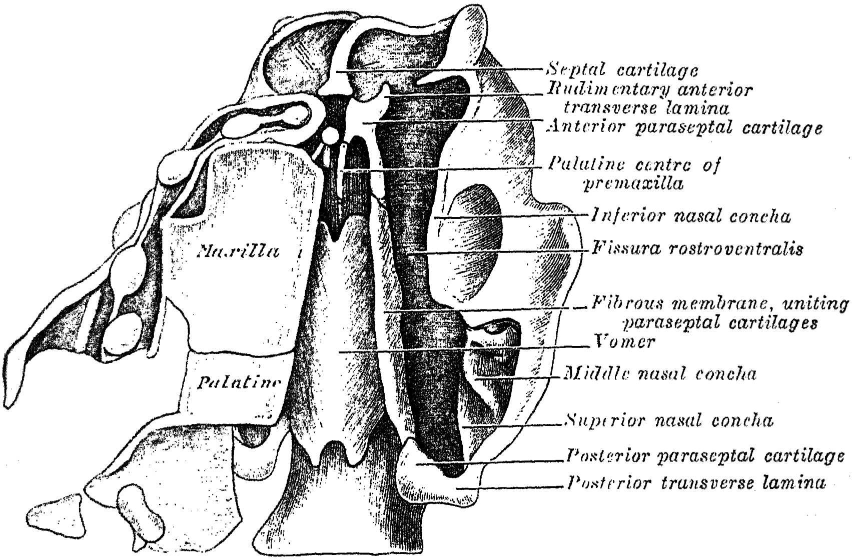
Chondrification of the small wing begins lateral to the optic nerve, and from this centre ingrowths extend in front of and behind the optic nerve and fuse with the hinder part of the interorbitonasal septum and so form the optic foramen. Ossification of the small wing begins just lateral to the optic foramen, but does not extend very far out; a considerable part of the cartilage disappears, and owing to this, the small wing, in the bony condition, is much smaller than the great wing.

The *nasal capsule* is situated in front of the small wings, and is well developed by the third month; it consists of a central part, or septum, and two lateral parts.

The septum lies partly under the brain (subcerebral) and partly in front of the brain (precerebral); its lower margin is almost horizontal and is, for a time, free; its anterior border intervenes between the anterior nares (fenestræ narinæ).

The lateral parts of the capsule are primarily suspended from the precerebral part of the septum; later they are connected with the subcerebral part of the septum by the lamina cribrosa of the ethmoidal bone. Each lateral part consists

Fig. 113.—The nasal capsule of a human embryo 65 mm. long. Ventral aspect. On the left side the floor of the capsule has been removed. (From a model by Professor Edward Fawcett.)



of an anterior, an intermediate and a posterior portion. The anterior and intermediate portions are separated externally by an anterolateral sulcus which corresponds internally with a semilunar crest; the lower end of this crest forms the uncinate process of the ethmoidal bone. The posterior and intermediate portions are separated by a faint postero-lateral sulcus which corresponds internally with the middle nasal concha. The lower edge of the lateral wall of the capsule is incurved to form the inferior nasal concha which, at the fifth month, becomes ossified and detached from the lateral wall of the capsule.

In man the floor of the cartilaginous nasal capsule is far from complete (fig. 113). In rodents and some marsupials it consists of an anterior and a posterior transverse

lamina connecting the lateral wall of the capsule with the septum; in front of the anterior lamina is the fenestra narina. The anterior and posterior transverse laminæ are connected by a bar of cartilage which runs backwards alongside the septum and forms the *common paraseptal cartilage*; the anterior part of this cartilage is bilaminar, and between the laminæ the organ of Jacobson is lodged; the posterior part is small and cylindrical.

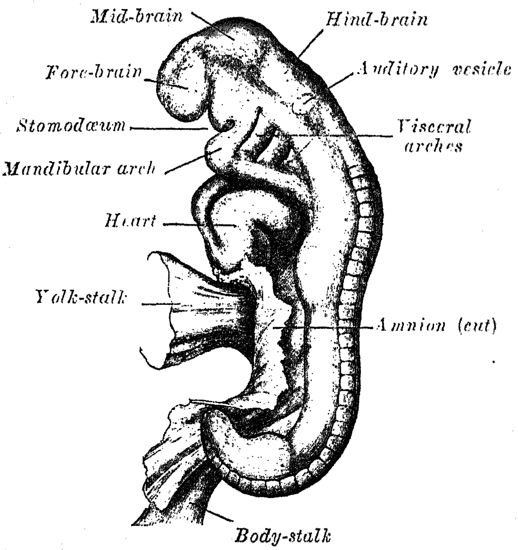
In man the greater part of the anterior transverse lamina is absent and thus the fenestra narina is continuous with the fenestra basalis, the two forming the fissura rostroventralis. Further, only the anterior and posterior segments of the common paraseptal cartilage are developed in man; these parts are termed the anterior and posterior paraseptal cartilages and are united to one another by fibrous membrane.

Part of the cartilaginous capsule is ossified to form the ethmoidal bone and the inferior nasal conchæ, part remains cartilaginous as the septal and alar cartilages of the nose, and part is replaced by membrane bones.

The ventral surface of the chondrocranium is indirectly connected with the cartilages of the visceral arches, the fate of which is described below.

The bones of the vault of the skull are of membranous formation, and are termed *dermal or covering bones*. They comprise the frontal and parietal bones, the upper part of the squama occipitalis (interparietal bone), and the squamæ and tympanic parts of the temporal bones. During the course of growth cartilage appears in the articular tubercle (eminentia articularis) of the temporal bone. Some of the dermal or covering bones remain distinct throughout life (e.g. parietal and frontal), while others join with the bones of the chondrocranium (e.g. interparietal and squamæ of temporals).

FIG. 114.—A human embryo between eighteen and twenty-one days. Left lateral aspect. (His.)



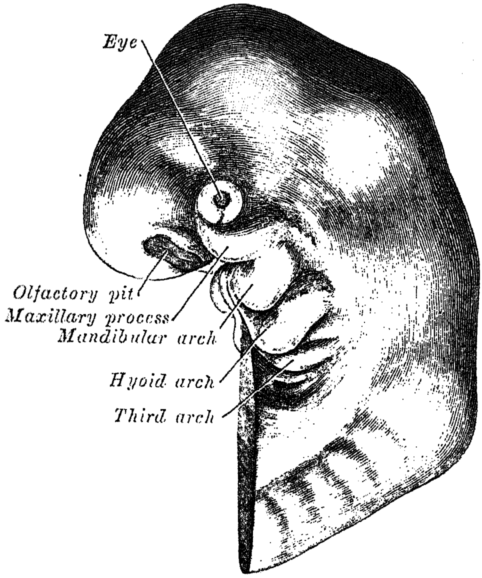
The **branchial or visceral arches and pharyngeal pouches.** In the lateral walls of the anterior part of the fore-gut five *pharyngeal pouches* appear (figs. 115, 116); each of the upper four pouches is prolonged into a dorsal and a ventral diverticulum. Over these pouches corresponding indentations of the ectoderm occur, forming what are known as the *branchial or outer pharyngeal grooves*. The mesoderm which intervenes between the pouches and the grooves is pressed aside for a time, and the ectoderm unites with the entoderm of the fore-gut along the floors of the grooves to form thin *closing membranes* between the fore-gut and the exterior; the mesoderm again penetrates between the entoderm and the ectoderm of these closing membranes. In gill-bearing animals the closing membranes disappear, and the grooves become the gill-clefts. Perforation does not occur in birds or mammals.

The branchial grooves separate a series of rounded bars or arches, the *branchial or visceral arches* in which thickening and consolidation of the mesoderm take place (figs. 114 to 116). The dorsal ends of these arches are attached to the sides of the head, while the ventral ends ultimately meet in the middle line of the neck. In all, six arches make their appearance, but of these only the first four are visible externally. The first arch is termed the mandibular, and the second the hyoid; the others have no distinctive names. In each arch the central part of the mesoderm consolidates and is then converted into a cartilaginous bar, consisting of right and left halves. Moreover, each arch is traversed by a nerve and by one of the primitive aortic arches.

The *mandibular arch* lies between the stomodæum or primitive mouth and the first branchial groove; from it are developed the lower lip, the mandible, the muscles

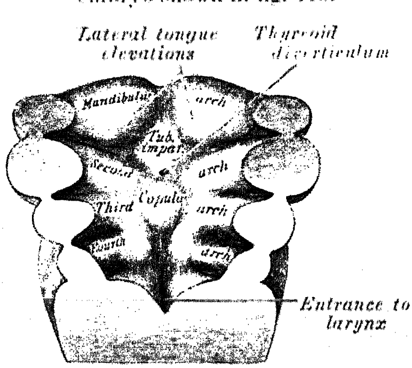
of mastication, and the anterior part of the tongue. Its cartilaginous bar is formed by what are known as *Meckel's cartilages* (right and left) (fig. 117). The dorsal end of each cartilage is ossified to form two of the three bones of the middle ear, viz. the malleus and incus; the ventral ends of the two cartilages meet in the region of the symphysis menti, and become ossified and incorporated with that part of the mandible which lies below and inside the medial and lateral incisors (Low). The portion immediately below the malleus and incus is replaced by fibrous membrane which constitutes the spheno-mandibular ligament, while the mandible is ossified in the connective tissue covering the remainder of the cartilage. From the dorsal ends of the mandibular arch a triangular process, the *maxillary process*, grows forwards on either side and forms the lower eyelid, the cheek, the lateral part of the upper lip, the zygomatic bone, and the greater part of the maxilla.

Fig. 115.—The head-end of a human embryo, about the end of the fourth week. Left lateral aspect. (From a model by Peter.)



The second or *hyoid arch* assists in forming the side and front of the neck. From the dorsal end of its cartilaginous bar the third bone of the middle ear, viz. the stapes, is developed, and subsequently becomes attached to the auditory capsule. From the ventral part of the arch the styloid process, stylohyoid ligament, and lesser cornu of the hyoid bone are developed; the glossopalatine arch indicates the position of the hyoid arch. The cartilage of the *third arch* gives origin to the greater cornu of the hyoid bone, and the ventral ends of the second and third arches unite with those of the opposite side, and form a transverse band, from which the body of the hyoid bone and the posterior part of the tongue are developed. From the cartilage of the *fourth arch* the thyreoid cartilage is developed; from the cartilages of the *fifth arch* the cricoid cartilage is formed (Fawcett).*

Fig. 116.—The floor of the pharynx of the embryo shown in fig. 115.



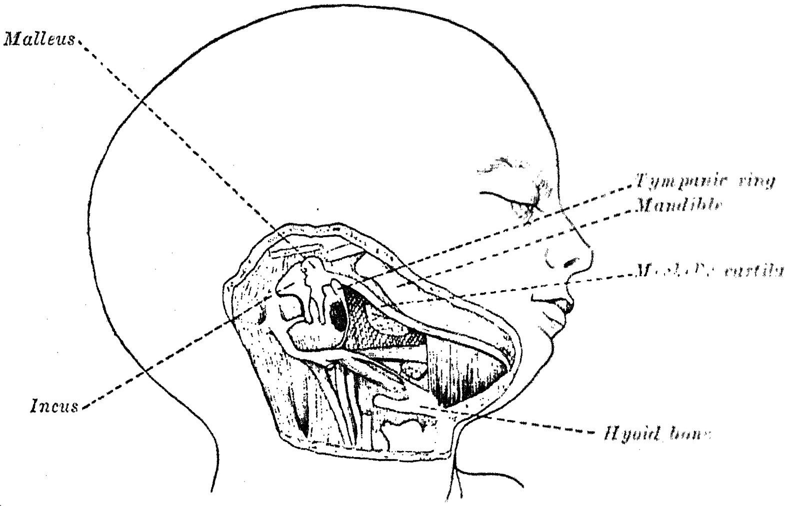
The mandibular and hyoid arches grow more rapidly than those behind them, with the result that the third and fourth arches recede from the surface and form the floor of a deep depression, the *sinus cervicalis*. The hyoid arch grows backwards and overlaps the sinus, the opening from which assumes the form of a narrow duct; this duct closes and converts the sinus into a vesicle which disappears before the end of the second month.

From the first branchial groove the concha of the auricula and the external acoustic meatus are developed, while around the groove there appear, on the mandibular and hyoid arches, several swellings from which the auricula or pinna is formed (p. 108). From the upper or dorsal parts of the first and second pharyngeal pouches the auditory tube and the tympanic cavity are developed (p. 107); the closing membrane between the mandibular and hyoid arches is invaded by mesoderm, and forms the tympanic membrane. No traces of the

*** Professor Edward Fawcett** (*Proceedings of the Anatomical Society of Great Britain and Ireland*, **1916**).

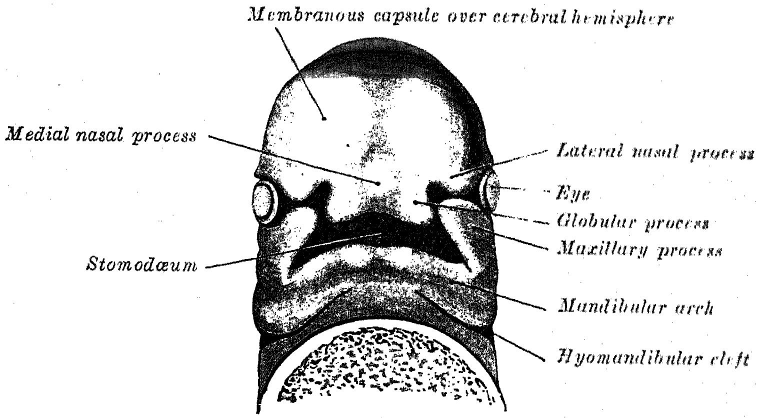
second, third, or fourth branchial grooves persist. The dorsal angle of the second pharyngeal pouch is named the *sinus tonsillaris*; in it the tonsil is developed, and above the tonsil a trace of the sinus persists as the supratonsillar fossa. The

FIG. 117.—The head and neck of a human embryo, eighteen weeks old, with Meckel's cartilage and the hyoid bar exposed. (After Kölliker.)



pharyngeal recess, or fossa of Rosenmüller, is by some regarded as a persistent part of the second pharyngeal pouch, but it is probably developed as a secondary formation. From the third pharyngeal pouch the thymus arises as an entodermal diverticulum on either side, and from the fourth pouches small diverticula project and become incorporated with the thymus, but in man they probably never form true thymus tissue. The parathyreoids arise as diverticula from the third and fourth pouches. From the fifth pouches the ultimobranchial bodies originate and are enveloped by the lateral prolongations of the median thyreoid rudiment; they do not, however, form true thyreoid tissue, nor are any traces of them found in the human adult.

FIG. 118.—The head of a human embryo about twenty-nine days old. Ventral aspect. (From a model by His.)



The **nose and face.**—During the fourth week two areas of thickened ectoderm, the *olfactory plates*, appear immediately under the fore-brain in the anterior wall of the stomodæum, one on either side of a region termed the *frontonasal process*. By the upgrowth of the surrounding parts these areas are converted into the *olfactory*

pits, which indent the frontonasal process and divide it into a *medial* and two *lateral nasal processes* (figs. 118, 119). The rounded lateral angles of the medial process are named the *globular processes* (His). From the ectodermal lining of the olfactory pits the epithelium of the nasal cavities is derived. The mesodermal plates which are represented on the surface by the globular processes are termed the *nasal laminæ*: these laminæ are at first some distance apart, but, gradually approaching, they ultimately fuse and form the nasal septum; the processes themselves meet in the middle line, and form the premaxillæ and the central part of the upper lip (fig. 122). The depressed part of the medial nasal process between the globular processes forms the lower part of the nasal septum or *columella*; while above this is seen a prominent angle, which becomes the future apex (figs. 118, 120), and still higher a flat area, the future bridge of the nose. The vomeronasal cartilage which supports the rudimentary organ of Jacobson and is found in the nasal septum, just above the nasopalatine recess, is derived from the anterior part of the common

FIG. 119.—The head-end of a human embryo about thirty or thirty-one days old. Ventral aspect. (From a model by K. Peter.)

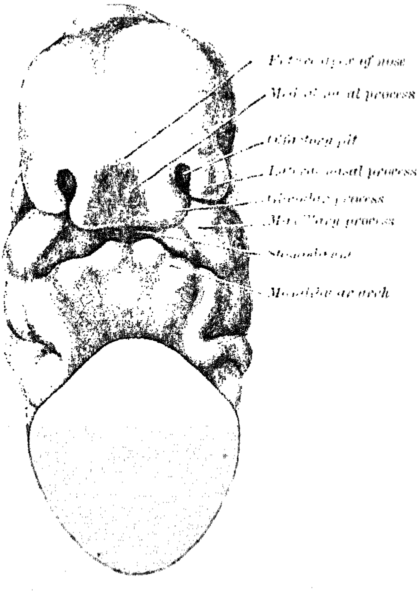
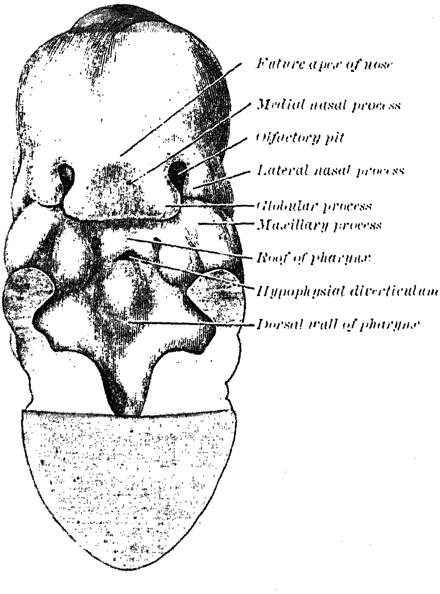


FIG. 120.—The same embryo as is shown in fig. 119, with the front wall of the pharynx removed.



paraseptal cartilage (p. 76). The lateral nasal process forms the ala of the nose, and from the cartilage of this process the lamina cribrosa and labyrinth of the ethmoidal bone, the inferior nasal concha, the lesser alar cartilages, and the crus laterale of the greater alar cartilage are developed. The lacrimal and nasal bones, and the frontal process of the maxilla are ossified in the membrane covering the cartilage of the lateral nasal process. The maxillary process is separated for a time from the lateral nasal process by a groove, the *naso-optic furrow*, which extends from the furrow encircling the eyeball to the olfactory pit. The maxillary processes ultimately fuse with the lateral nasal and globular processes, and form the lateral parts of the upper lip and the posterior boundaries of the nares (figs. 121, 122). From the third to the fifth month the nares are filled by masses of epithelium, on the breaking down and disappearance of which the permanent openings are produced. By the fusion of the maxillary processes with the nasal and globular processes in the roof of the stomodæum the *primitive palate* (fig. 123) is formed, and the olfactory pits extend backwards above it. The posterior end of each pit is closed by an epithelial membrane, the *bucconasal membrane*, formed by the apposition of the nasal and stomodæal epithelium. About the fifth week the bucconasal membranes rupture and the *primitive choanæ* or openings between the olfactory pits and the stomodæum are established. The floor of the nasal cavity is completed by the development of a pair

of shelf-like *palatine processes* which appear about the sixth week and extend medialwards from the maxillary processes (figs. 124, 125); the palatine processes coalesce with each other and with the nasal septum in the middle line, and constitute the entire hard palate, except a small portion in front which is formed by the premaxillæ. The

FIG. 121.—The face of a human embryo of about eight weeks, in which the nose and mouth are formed. (From a model by His.)

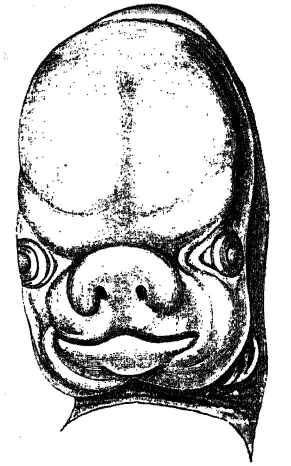
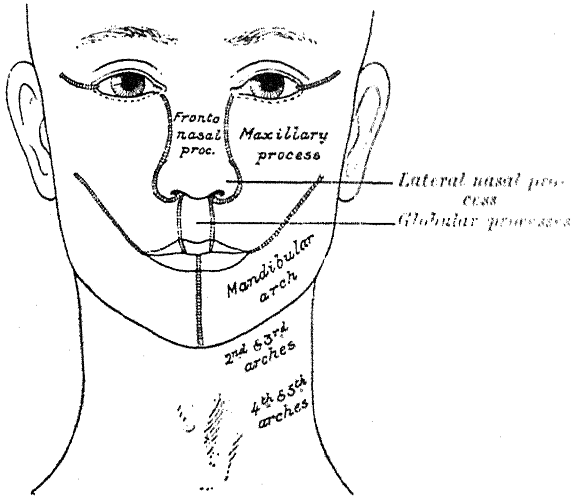
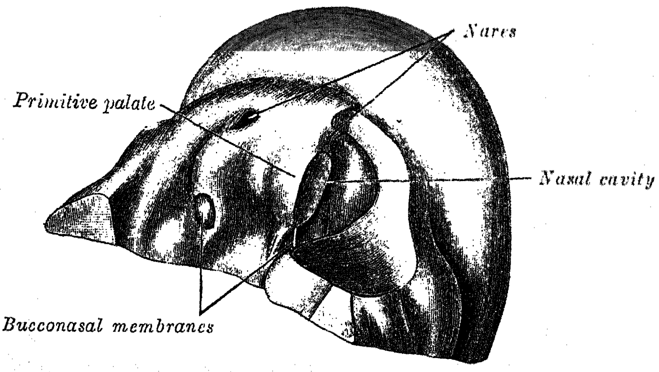


FIG. 122.—A diagram showing the parts of the adult face and neck which are related to the frontonasal and maxillary processes and the branchial arches.



soft palate is formed by two secondary backward growths, one on either side, from the palatine processes; into these the palatine muscles extend, and the two parts ultimately join to form the soft palate and uvula. Two apertures persist for a time between the palatine processes and the premaxillæ, and represent the permanent channels which in the lower animals connect the nose and mouth. The union of the parts which form the palate commences in front, the premaxillary and palatine processes joining in the eighth week of fœtal life, while the region of the future hard palate is completed by the ninth week, and that of the soft palate by the

FIG. 123.—The primitive palate of a human embryo about thirty-seven or thirty-eight days old. (From a model by K. Peter.)



On the left side the lateral wall of the nasal cavity has been removed.

eleventh week. By the completion of the palate the *permanent choanæ* are formed and are situated a considerable distance behind the primitive choanæ. The nasal cavity is divided by a cartilaginous septum, the anterior part of which persists as the septal cartilage of the nose, but the posterior and upper parts are replaced by the

omer and the lamina perpendicularis of the ethmoidal bone. On either side of e nasal septum, at its lower and anterior part, the ectoderm is invaginated to rm a diverticulum which extends backwards and upwards into the nasal septum nd is supported by a curved plate of cartilage. These diverticula form the

FIG. 124.—The roof of the mouth of a human embryo about two and a half months old, showing the mode of formation of the palate. (From a model by His.)

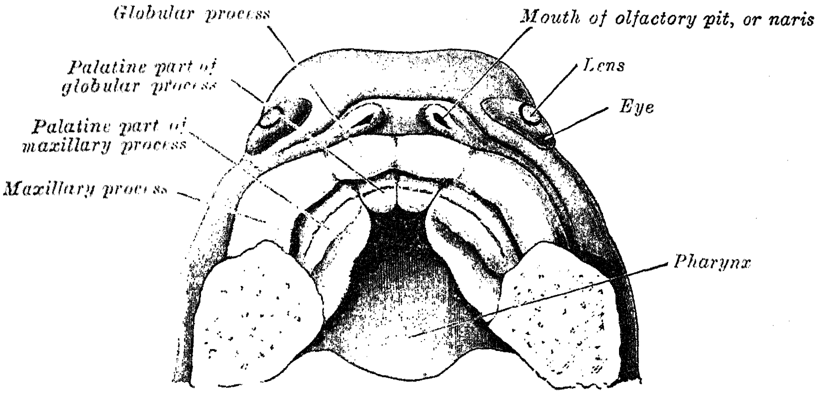
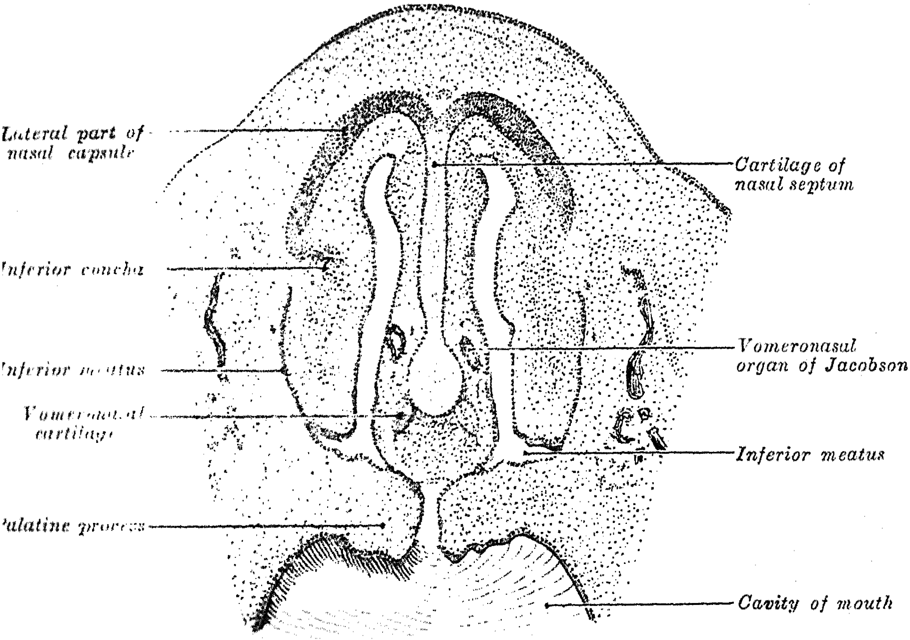


FIG. 125.—A frontal section through the nasal cavities of a human embryo 28 mm. long. (Kollmann.)



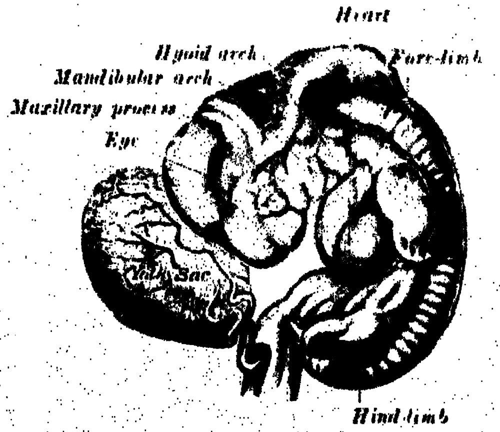
udiments of the *vomeronasal organs* of Jacobson, which open below, close to the unctions of the premaxillæ and maxillæ.*

* J. Ernest Frazer (Hunterian Lecture, *Lancet*, July 8, 1916) maintains that the increase in ze of the nasal cavities takes place in an upward and backward direction, and the septum is mply the part of the roof left undisturbed between the paired upgrowths. He also points ut that by the ninth week the primitive choanæ extend from the primitive palate to the top f the cavity of the mouth, and when the palatal folds meet they fuse with the lower two-hirds or three-fourths of the septum, while the upper one-fourth or so of the septum remains etween the upper parts of the openings which constitute the permanent choanæ.

Applied Anatomy.—*Cleft palate* is a common malformation. The cleft usually starts posteriorly, and its most elementary form is a bifid uvula; or the cleft may extend through the soft palate; or the posterior part of the hard palate may be involved as far forwards as the incisive foramen. In the severest forms, the cleft passes between the incisive bone or premaxilla and the rest of the maxilla, and extends through the alveolar process, between the lateral incisor and canine teeth. The palatine portion of the premaxilla consists of a medial part corresponding to the medial incisor, and a lateral part to the lateral incisor. These two parts may fail to unite, and the cleft then runs between the central and lateral incisor teeth. The cleft may affect one or both sides; if the latter, the premaxillæ are frequently displaced forwards and remain united to the septum of the nose, the deficiency in the alveolus being complicated with a cleft in the lip (hare-lip). Where the alveolus is not implicated, the cleft is usually in the median line, but occasionally it is unilateral and in some cases bilateral. In those cases where the palatine processes fail to unite with each other and with the nasal septum, the cleft of the palate is median; where one palatine process unites with the nasal septum, the other failing to do so, the cleft in the palate is unilateral. In some cases where the palatine processes fail to meet in the middle, the nasal septum may grow downwards between them and thus produce a bilateral cleft.

The limbs.—In the third week the limbs begin to make their appearance as small elevations or buds from a slight lateral ridge at either side of the trunk (fig. 126). Prolongations from several primitive segments extend into each bud, and carry with them the anterior divisions of the corresponding spinal nerves: the nerves supplying the limbs indicate the number of primitive segments which contribute to their formation—the upper limb being derived from seven, viz. fourth cervical to second thoracic inclusive, and the lower limb from ten, viz. twelfth thoracic to fourth sacral inclusive. The axial part of the mesoderm of the limb-bud condenses and is converted into its cartilaginous skeleton, and by the ossification of this the bones of the limbs are formed. The limbs are at first directed backwards nearly parallel to the long axis of the trunk; by the sixth week their long axes are at right angles to that of the trunk, and the three chief divisions of each limb are marked off by furrows—arm, forearm, and hand in the upper limb; thigh, leg, and foot in the lower (fig. 127). The future *flexor* surface of the limb is directed ventrally; the *extensor* surface, dorsally; one border, the *pre-axial*, looks towards the cephalic end of the embryo, and the other, the *post-axial*, towards the caudal end. The lateral epicondyle of the humerus, the radius, and the thumb lie along the pre-axial border of the upper limb; the medial epicondyle of the femur, the tibia, and the great toe along the corresponding border of the lower limb. The limbs next undergo a rotation or torsion through an angle of 90° around their long axes, the rotation being effected almost entirely at the limb girdles. The rotation of the upper limb is outwards and forwards; that of the lower limb is inwards and backwards. As a consequence of this rotation the pre-axial (radial) border of the fore-limb is directed lateralwards, and the pre-axial (tibial) border of the hind-limb medialwards; thus the flexor surface of the fore-limb is turned forwards, and that of the hind-limb backwards. The pre-axial part is derived from the anterior primitive segments, the post-axial from the posterior primitive segments of the limb-bud; and this explains, to a large extent, the innervation of the adult limb, the nerves of the more anterior segments being distributed along the pre-axial (radial or tibial), and those of the more posterior segments along the post-axial (ulnar or fibular) border of the limb.

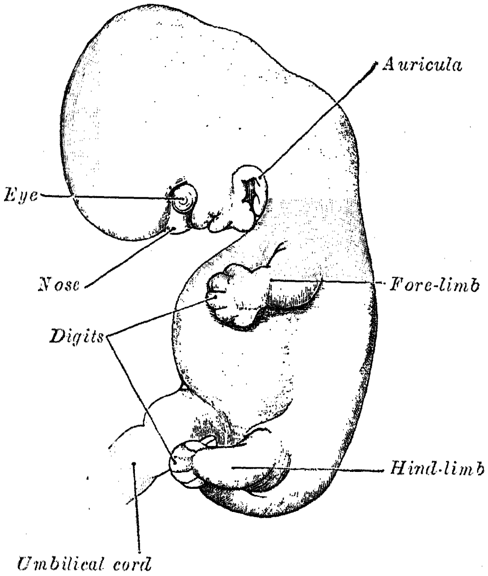
FIG. 126.—A human embryo between thirty-one and thirty-four days old. (His.)



The joints.—The mesoderm from which the different parts of the skeleton are formed at first shows no differentiation into masses corresponding with the individual bones; thus, continuous cores of mesoderm form the axes of the limb-buds

and a continuous column of mesoderm the future vertebral column. The first indications of the differentiation of the bones and joints are circumscribed condensations of the mesoderm; these condensed parts become chondrified and finally ossified to form the bones of the skeleton. The intervening non-condensed portions consist at first of undifferentiated mesoderm, which may be converted into fibrous tissue as in the case of the skull bones, a synarthrodial joint being the result; or it may become partly cartilaginous, in which case an amphiarthrodial joint is formed; or it may become looser in texture, a cavity ultimately appearing in its midst, while the cells lining the sides of this cavity form a synovial stratum, and thus a diarthrodial joint is developed; in some diarthrodial joints portions of the mesoderm persist and form articular discs.

Fig. 127.—A human embryo about six weeks old. (His.)



The tissue surrounding the original mesodermal core forms fibrous sheaths for the developing bones (perichondrium and periosteum) which are continued between the ends of the bones over the synovial strata as the fibrous capsules of the joints. These capsules are not of uniform thickness, so that in them may be recognised specially strengthened bands which are described as ligaments. This, however, is not the only method of formation of ligaments. In some cases by modification of, or derivations from, the tendons surrounding the joint, additional ligamentous bands are provided to strengthen the articulations.

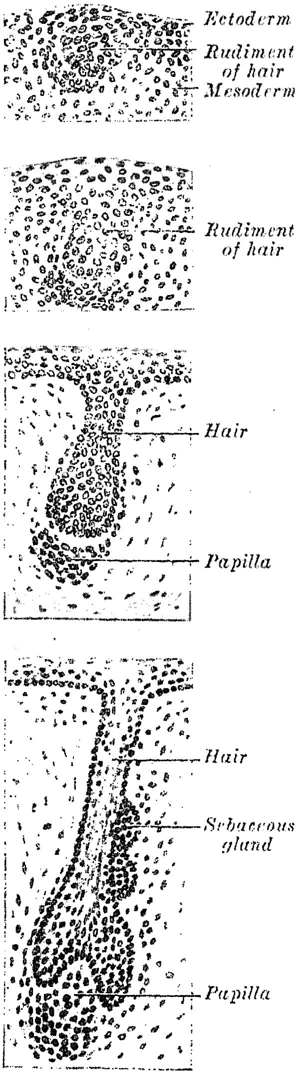
The **muscles.**—The voluntary muscles are developed from the myotomes of the primitive segments. Portions of the myotomes retain their position on the sides of the neural tube, where they may remain distinct from each other and form the short muscles of the vertebral column, or fuse with corresponding portions of neighbouring myotomes to form the Sacrospinales and their continuations. Other portions of the myotomes extend into the trunk wall where again they may retain their segmental condition, as in the Intercostales, or may fuse with adjacent segments to form the flat muscles of the abdominal wall. Finally, portions of the myotomes wander into the limb-buds and there undergo fusions and alterations in form to produce the limb muscles. The original segmental character of the limb muscles is therefore lost, but their segmental nerve supplies are retained. Some of the limb muscles expand and migrate secondarily towards the mid-dorsal line (e.g. Trapezius and Latissimus dorsi) or towards the mid-ventral line (e.g. Pectoralis major). Again, muscles may migrate in a cephalic direction (e.g. the facial muscles which are derived from the hyoid arch), or in a caudal direction (e.g. the Serratus anterior). In all cases they carry with them the segmental nerves of the myotomes from which they are derived; one example of this will suffice, viz. the Serratus anterior, which is derived from the fifth, sixth, and seventh cervical segments as is indicated by its nerves of supply. In man and the higher vertebrates many of the derivatives of the myotomes degenerate and are converted into aponeuroses (e.g. the galea aponeurotica, and the aponeuroses of the abdominal muscles) or ligaments (e.g. the sacrotuberous ligament and the fibular collateral ligament of the knee).

The involuntary muscles are derived from the splanchnopleure mesoderm.

The **skin and its appendages.**—The epidermis, hairs, nails, sebaceous and sudoriferous glands are developed from the ectoderm, the corium or true skin from the mesoderm. The ectoderm at first consists of a single stratum of cells, but by the fifth week two strata can be recognised, a superficial, named the *epitrichium*, consisting of flat cells, the nuclei of which stain readily, and a deep,

named the *stratum germinativum*, consisting at first of cubical, but later of columnar, cells. By multiplication and differentiation of the cells of the stratum germinativum the different layers of the epidermis are developed. Towards the end of the third month the mesoderm condenses to form the corium, and at about the same time the subcutaneous areolar tissue is differentiated; in the fourth month the dermal papillæ begin to make their appearance. A considerable desquamation of the epidermis takes place, and this desquamated epidermis, mixed with sebaceous secretion, constitutes the *vernix caseosa*, with which the skin is smeared during the last three months of fœtal life.

Fig. 128.—Successive stages in the development of a hair.



The *hairs* (fig. 128) originate as thickenings of the epidermis which grow obliquely downwards as solid buds into the corium, each bud consisting of an outer stratum of columnar cells and a core of polygonal cells. The deep end of each bud expands to form the hair-bulb which is moulded over a papilla of condensed mesoderm. The cells of the hair-bulb proliferate and form a cone of cells, from which the scapus or shaft of the hair and its inner sheath are developed; the hairs gradually lengthen by growth at the hair-bulb, and ultimately project on the surface.

The *sebaceous glands* originate as lateral outgrowths from the sides of the hair-buds, and, pushing their way into the mesoderm, divide into three or four oval or flask-shaped alveoli, the lining cells of which are derived from the stratum germinativum.

The rudiments of the *sudoriferous or sweat glands* make their appearance on the palms of the hands and soles of the feet in the fourth month, and closely resemble the rudiments of the hairs, each beginning as a solid downgrowth of the ectoderm. The ectodermal downgrowth lengthens, and its deeper part coils on itself and forms the body of the gland. A lumen is developed in the downgrowth about the seventh month of fœtal life, and opens on the surface by a duct which is lined with two layers of cells. In the secreting part of the gland the outer layer of cells is modified to form a stratum of smooth muscle-fibres which lies between the epithelium of the gland and the basement-membrane. Many sudoriferous glands arise as ectodermal downgrowths from the superficial portions of the hair-follicles and later acquire independent openings on the surface of the skin.

The *mammary gland* may be looked upon as a collection of greatly modified sudoriferous glands; the epithelial lining of its ducts and alveoli is derived from the ectoderm, its supporting connective tissue from the mesoderm. On either side of the ventral surface of young embryos a thickened band of ectoderm, termed the *milk-ridge*, extends obliquely from the axilla to the inguinal region, and in some of the lower mammals mammæ are developed at intervals along this ridge. In man only one mamma, as a rule, is developed on either side of the middle line, but supernumerary glands or nipples are sometimes found above or below the fully developed gland.

The rudiment of the mamma appears as a thickening and subsequent downgrowth of the ectoderm; from this downgrowth fifteen or twenty solid cords branch off, each cord representing a future lactiferous tubule and lobe of the gland. The

deep ends of the cords subdivide in the mesoderm and form the alveoli of the gland. The region where the ectodermal thickening occurred is subsequently raised to form the nipple, and about the time of birth the tubules and alveoli become canalised. At the age of puberty, and in a greater degree towards the end of pregnancy, a marked enlargement of the gland, and a development of additional lobules and alveoli, take place.*

The rudiments of the *nails* can be seen in embryos of about 4·5 cm. in length, and appear as *primary nail-fields* of ectoderm on the dorsal surfaces of the terminal phalanges of the digits. At the proximal end and sides of each nail-field the epidermis is invaginated to form the nail-folds, while the distal end, which will ultimately form the free end of the nail, is bounded by a shallow groove. The nail is developed from the posterior nail-fold and consists of modified stratum lucidum. The stratum corneum covers the nail and forms the *eponychium*; this disappears from the surface of the nail, with the exception of a narrow fold which overlaps the proximal part of the lunule of the nail.

THE DEVELOPMENT OF THE NERVOUS SYSTEM AND SENSE-ORGANS

The nervous system is derived from the ectoderm and first appears as the neural groove on the dorsal aspect of the embryo (fig. 80). By the elevation and ultimate fusion of the neural folds, the groove is converted into the neural tube (fig. 82). The anterior end of the tube expands to form the three primary brain-vesicles; the cavity of the tube is subsequently modified to form the ventricular cavities of the brain and the central canal of the medulla spinalis; from the wall the nervous elements and the neuroglia of the brain and medulla spinalis are developed.

The **medulla spinalis.**—At first the wall of the neural tube is composed of a single layer of columnar ectodermal cells. The lateral parts of the wall soon thicken, while the dorsal and ventral parts remain thin, and are named the *roof-* and *floor-plates* (figs. 129, 131). A transverse section of the tube at this stage presents an oval outline and a slit-like lumen. The cells which constitute the wall of the tube proliferate rapidly, lose their cell-boundaries and form a syncytium consisting at first of dense protoplasm with closely packed nuclei, but later opening out and forming a loose meshwork with the strands radiating from the central canal. Three layers of this syncytium may be defined—an internal or ependymal, an intermediate or mantle, and an external or marginal (fig. 129). The *ependymal layer* is ultimately converted into the ependyma of the central canal; the processes of its cells pass outwards towards the periphery of the medulla spinalis. The *marginal layer* is devoid of nuclei, and later forms the supporting framework for the white funiculi of the medulla spinalis. The *mantle layer* represents the future grey columns of the medulla spinalis; its cells are differentiated into two sets, viz. (*a*) *spongioblasts* or young neuroglia-cells, and (*b*) *neuroblasts* or young nerve-cells (fig. 130). The spongioblasts are connected to another one by filaments of the syncytium; in these, fibrils are developed, so that as the neuroglia cells become defined they exhibit their characteristic mature appearance with multiple processes proceeding from each cell. The neuroblasts are large, round or oval, and first make their appearance between the ependymal cells on the sides of the central canal. They increase rapidly in number, so that by the fourth week they form an almost continuous layer on either side of the central canal. No neuroblasts are found in the roof- or floor-plates; the roof-plate retains, in certain regions of the brain, its epithelial character; elsewhere, its cells become spongioblasts. The neuroblasts or young nerve-cells migrate from the sides of the central canal into the mantle layer, and at the same time become pear-shaped; the tapering part of the cell undergoes still further elongation, and forms the axis-cylinder of the cell.

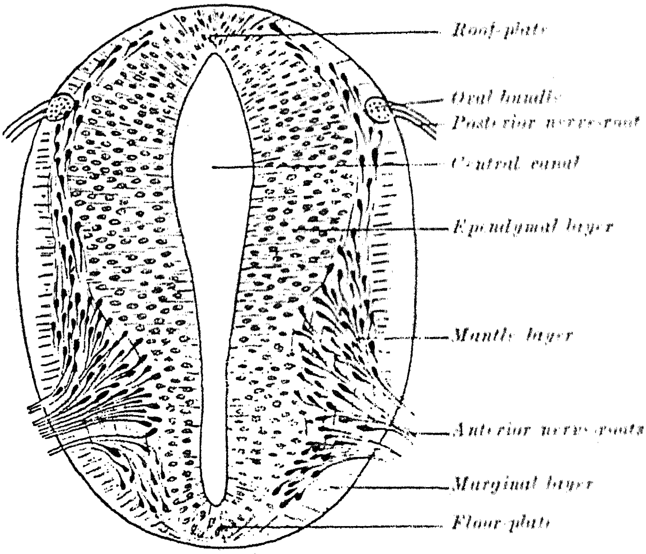
The lateral walls of the medulla spinalis increase in thickness, and the central canal widens out near its dorsal extremity, and assumes a somewhat lozenge-shaped appearance. The widest part of the canal subdivides the lateral wall of the neural tube into a *dorsal or alar*, and a *ventral or basal lamina* (fig. 131), a subdivision which extends into the brain. The dorsal part of the canal is reduced to a mere slit which is subsequently obliterated by the approximation and fusion of its walls; the ventral part persists as the central canal of the adult medulla spinalis. The

* Consult, 'The mammary apparatus of the Mammalia,' by Ernst Bresslau. 1920.

caudal end of the canal exhibits a conical expansion which is known as the *terminal ventricle.*

The ventral part of the mantle layer increases in thickness, and on cross-section appears as a triangular patch between the marginal and ependymal layers. This thickening is the rudiment of the anterior column of grey substance, and contains many motor neuroblasts, the axis-cylinders of which pass out through the marginal layer and form the anterior roots of the spinal nerves (fig. 129). Dart and Shellshear * are of opinion that the motor neuroblasts originate in the myotomes, and migrate into the wall of the neural tube. The thickening of the mantle layer gradually extends in a dorsal direction, and forms the posterior column of grey substance. In the thoracic and upper lumbar regions a lateral or intermediate column of grey substance is differentiated. The axons of the cells of this column form the splanchnic efferent nerves; they emerge in the anterior nerve-roots, and pass through the white rami communicantes to the ganglia of the sympathetic

Fig. 129.—A transverse section through the medulla spinalis of a human embryo four weeks old. (His.)



trunk. The axons of many of the neuroblasts in the alar lamina run forward, cross in the floor-plate to the opposite side of the medulla spinalis, and form the rudiment of the anterior white commissure.

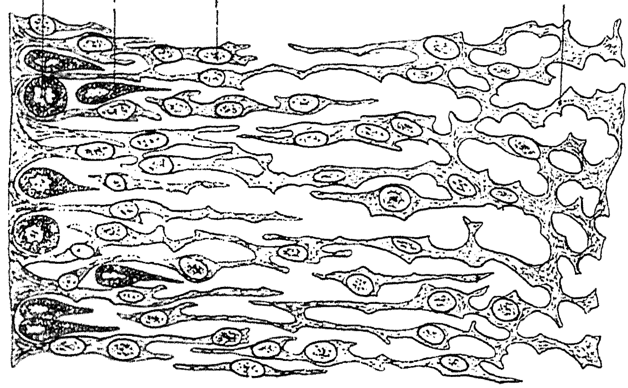
About the end of the fourth week nerve-fibres appear in the marginal layer. The first to develop are the short intersegmental fibres from the neuroblasts in the mantle zone, and the fibres of the posterior roots of the spinal nerves which pass into the medulla spinalis from the cells of the spinal ganglia. By the sixth week the fibres of the posterior roots of the spinal nerves form a well-defined *oval bundle* in the peripheral part of the alar lamina; this bundle increases in size, and spreading towards the middle line forms the rudiment of the posterior funiculus. The long intersegmental fibres begin to appear about the third month, and the cerebrospinal fibres about the fifth month. All nerve-fibres are at first destitute of medullary sheaths, and different groups of fibres receive their sheaths at different times, e.g. the anterior and posterior nerve-roots are medullated about the fifth month, the cerebrospinal fibres after the ninth month.

By the growth of the anterior columns of grey substance, and by the increase in size of the anterior funiculi, an anterior furrow is formed between the lateral halves of the medulla spinalis; this gradually deepens to form the anterior median fissure (fig. 131, B). The mode of formation of the posterior septum is somewhat uncertain. It is probably produced by the growing together of the walls of the posterior part of the central canal and by the development from its ependymal

* Raymond A. Dart and Joseph L. Shellshear, *Journal of Anatomy*, vol. lvi. January 1922.

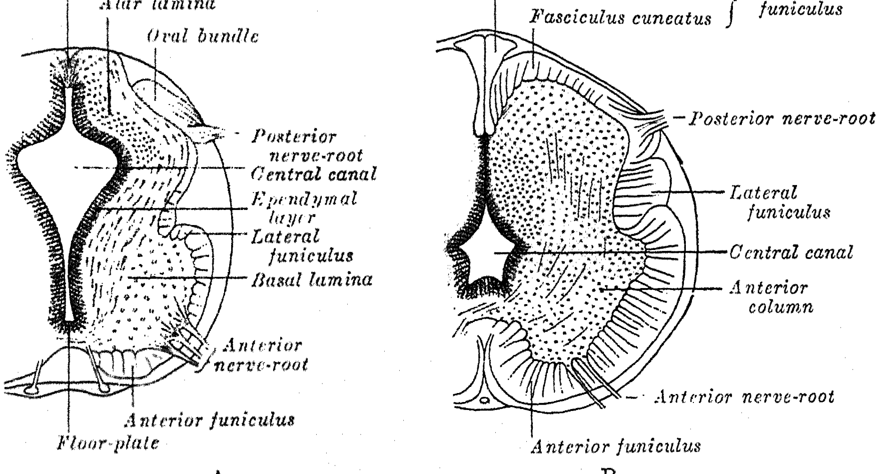
cells of a septum of fibrillated tissue which separates the future funiculi graciles. The cervical and lumbar enlargements appear simultaneously with the development of the limb-buds.

FIG. 130.—A transverse section through the medulla spinalis of a human embryo at the beginning of the fourth week. (After His.) The left edge of the figure corresponds to the lining of the central canal.



In early fœtal life the medulla spinalis occupies the entire length of the vertebral canal, and the spinal nerves pass outwards at right angles. When the embryo has attained a length of 30 mm. the vertebral column begins to grow farther caudalwards than the medulla spinalis, and the latter gradually assumes a higher position within the vertebral canal, the principal part of this upward migration occurring during the first half of fœtal life. By the twenty-fifth week of fœtal life the terminal ventricle of the medulla spinalis (p. 86) has ascended from the level of the second

FIG. 131.—Transverse sections through the medullæ spinales of human embryos. A, about four and a half weeks old. B, about three months old. (His.)



coccygeal vertebra to that of the third lumbar vertebra, or a distance of nine segments, and there remain but two segments before the adult position is reached (Streeter *). A delicate filament, the *filum terminale*, extends from the lower end

* George L. Streeter, *American Journal of Anatomy*, vol. 25, 1919.

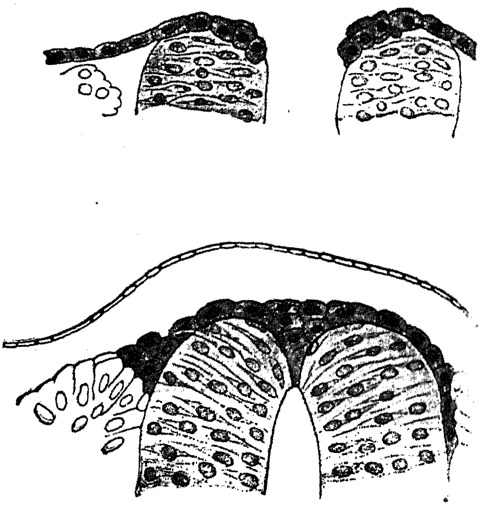
of the medulla spinalis as far as the first piece of the coccyx, and represents that part of the fœtal medulla spinalis which is caudal to the second coccygeal segment, and has become converted into a fibrous strand. This strand, like the sacral nerve-roots, elongates in adaptation to the ascending displacement of the medulla spinalis.

The spinal nerves.—Each spinal nerve is attached to the medulla spinalis by an anterior and a posterior root.

The fibres of the anterior or motor roots are formed by the axons of the neuroblasts which lie in the ventral part of the mantle layer; these axons grow out through the overlying marginal layer into the myotomes of the primitive segments, and are ultimately aggregated to form the anterior nerve-roots (fig. 129).

The fibres of the posterior roots are developed from the cells of the spinal ganglia. Before the neural groove is closed to form the neural tube a ridge of ectodermal cells, the *ganglion-ridge* or *neural crest* (fig. 132), appears along the prominent margin of each neural fold. When the folds meet in the middle line the two ganglion-ridges fuse and form a wedge-shaped area along the line of closure of the tube. The cells of this area proliferate rapidly opposite the primitive segments to form a series of oval-shaped masses which lose their connexions with the neural tube and then migrate for a short distance in a lateral and ventral direction. From the ventral part of each mass a small portion is detached to form a sympathetic ganglion, while the remainder is converted into a spinal ganglion. These spinal ganglia are arranged symmetrically on the two sides of the neural tube and, except in the region of the tail, are equal in number to the primitive segments. The cells of the ganglia, like the cells of the mantle layer, are of two kinds, viz. spongioblasts and neuroblasts. The spongioblasts develop into the neuroglial cells of the ganglia. The neuroblasts, at first round or oval in shape, soon assume the form of spindles the extremities of which gradually elongate into central and peripheral processes. The central processes grow medialwards and, becoming connected with the neural tube, constitute the fibres of the posterior nerve-roots, while the peripheral processes grow lateralwards to mingle with the fibres of the anterior root in the spinal nerve. As development proceeds the original bipolar form of the cells changes; the two processes become approximated until they ultimately arise from a single stem in a T-shaped manner. The bipolar form is retained in the retina and in the ganglia of the acoustic nerve. Some recent observers hold, however, that the T-form is derived from the branching of a single process which grows out from the cell.

FIG. 132. Two stages in the development of the neural crest in the human embryo. (Lenhossék.)

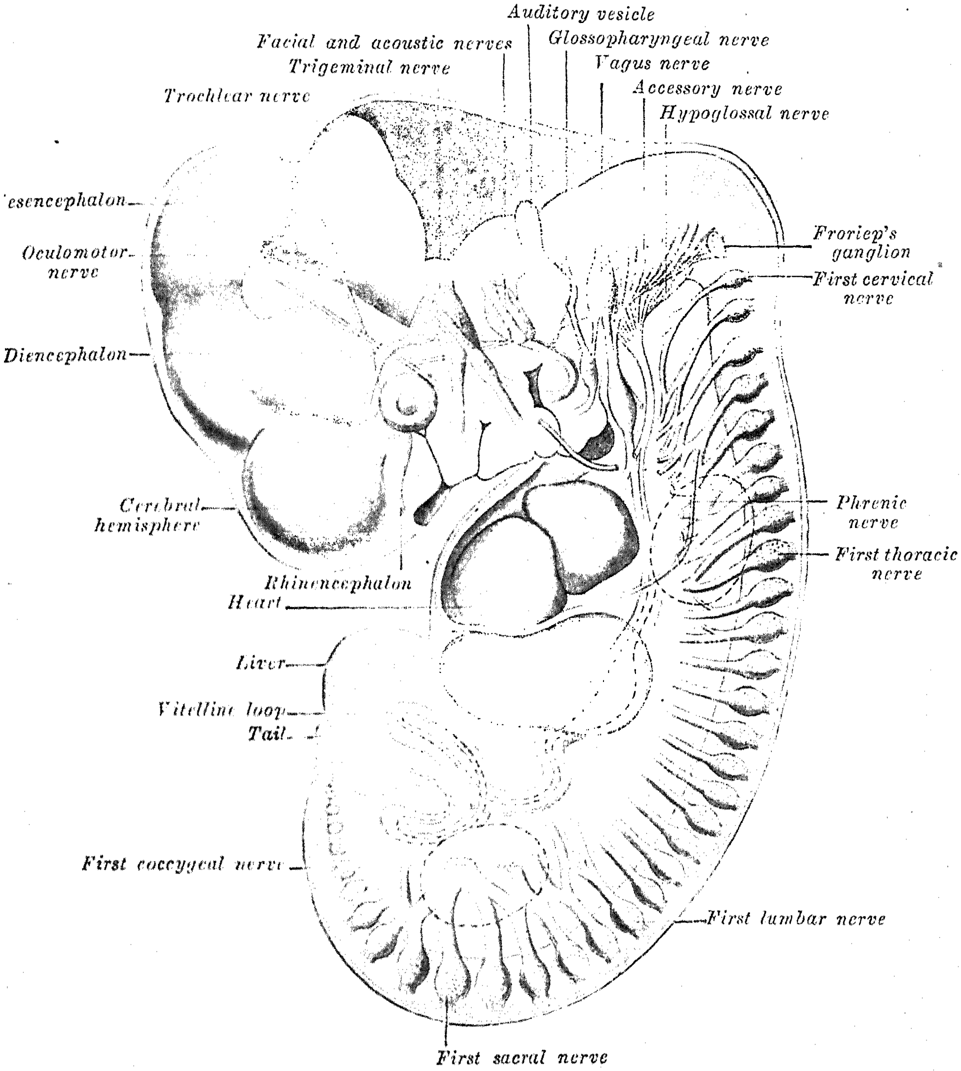


Many embryologists maintain (1) that each motor nerve-cell gives origin to a single motor nerve-fibre which later becomes connected to its own special myotome, and (2) that each sensory nerve-cell gives origin to two processes, a central which grows into the medulla spinalis or into the brain, and a peripheral which passes outwards to unite with the sense-organ supplied by the nerve. It is, however, probable that the myotomes and the peripheral sense-organs are from the first connected with the central nervous system, and that this connexion is never lost. In *Lepidosiren paradoxa*, Graham Kerr * has traced back the development of the motor nerve-trunk to a period in which it is represented by a bridge of soft granular protoplasm connecting the medulla spinalis and myotome at a stage when these structures are in close apposition. As the myotome is pushed outwards it remains connected with the medulla spinalis by the ever-lengthening strand of nerve, which soon loses its granular protoplasmic character and assumes a fibrillated appearance. A similar

* J. Graham Kerr, *Transactions of the Royal Society of Edinburgh*, vol. xli. part i. 1903-4.

condition probably exists regarding the development of sensory nerve-fibres, for Cameron and Milligan * have shown that in early embryonic life the cell-elements of the sense-epithelium of the auditory vesicle are connected with those of the hind-brain by a continuous tract of nucleated protoplasm (syncytium) which is never

FIG. 133.—A human embryo 10·2 mm. long, showing the peripheral nerves. (After a reconstruction by His.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



The abducent nerve is not labelled, but is seen passing forwards to the eye under the mandibular and maxillary nerves.

severed. This syncytium, at first undifferentiated, becomes fibrillated longitudinally to form a continuous tract of nerve-fibres (the future auditory nerve) uniting the sense-epithelium of the auditory organ with the hind-brain.

The anterior and posterior nerve-roots join immediately beyond the spinal ganglion to form the *spinal nerve* (fig. 133), which then divides into anterior, posterior, and visceral divisions. The anterior and posterior divisions proceed directly to their areas of distribution without further association with ganglion-cells. The visceral

* 'The development of the auditory nerve in vertebrates,' *Journal of Anatomy and Physiology*, vol. xliv.

divisions are distributed to the thoracic, abdominal, and pelvic viscera, to reach which they pass through the sympathetic trunk, and many of the fibres of these divisions form arborisations around the ganglion-cells of this trunk. Visceral divisions are not given off from all the spinal nerves; they form two groups, viz. (*a*) *thoracicolumbar*, from the thoracic and the first and second lumbar nerves; and (*b*) *sacral*, from the second, third and fourth sacral nerves.

The **brain** is developed from the cephalic end of the neural tube, which at an early period expands into the three primary cerebral vesicles (fig. 81). These are marked off from each other by constrictions, and are named the *rhombencephalon* or *hind-brain*, the *mesencephalon* or *mid-brain*, and the *prosencephalon* or *fore-brain*—the first being continuous with the medulla spinalis. As the result of the unequal growth of its different parts three flexures appear in the brain; two of these flexures are concave ventrally and are associated with corresponding flexures of the head. The first appears in the region of the mid-brain, and is named the *ventral cephalic flexure* (figs. 134, 139); the fore-brain bends in a ventral direction around the anterior end of the notochord and fore-gut until its floor lies almost parallel with that of

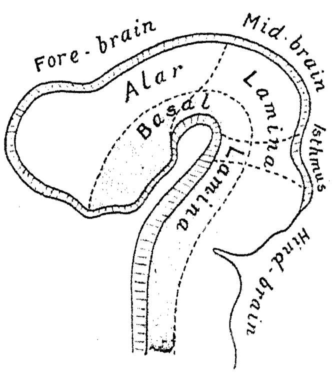


FIG. 134.—A diagram to illustrate the alar and basal laminæ of the brain vesicles. (His.)

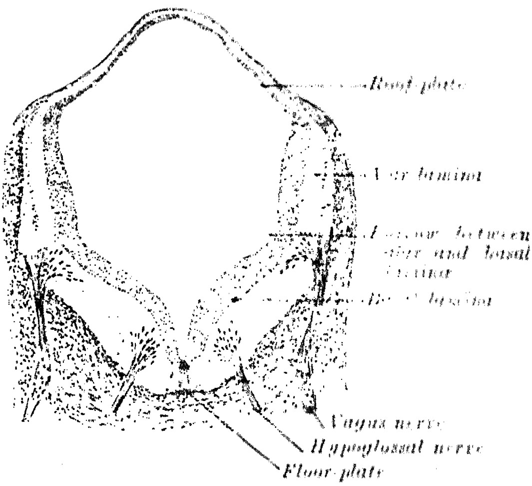


FIG. 135.—A transverse section through the medulla oblongata of a human embryo. × 32. (From Kollmann's Entwickelungsgeschichte.)

the hind-brain. The mid-brain is for a time the most prominent part of the brain, since its dorsal surface corresponds with the convexity of the flexure. The second bend appears at the junction of the hind-brain and medulla spinalis, and is termed the *cervical flexure* (fig. 138). It increases from the third to the end of the fifth week, when the hind-brain forms nearly a right angle with the medulla spinalis; after the fifth week erection of the head takes place and the cervical flexure diminishes and disappears. The third bend is named the *pontine flexure* (fig. 140), because it is found in the region of the future pons (Varolii). It differs from the other two in that (*a*) its convexity is forwards, and (*b*) it does not affect the head.

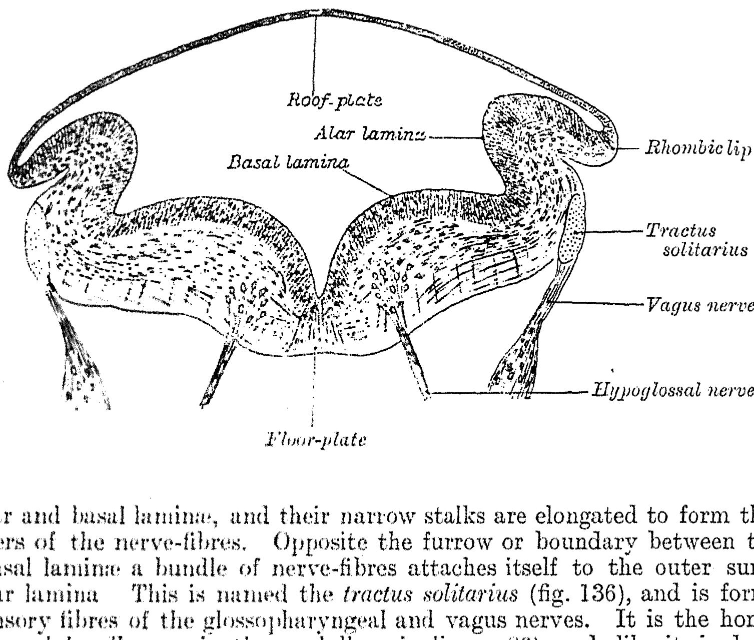
The lateral walls of the brain-tube, like those of the medulla spinalis, are divided by internal furrows into dorsal or alar and ventral or basal laminæ (figs. 134, 135).

The **rhombencephalon** or **hind-brain**.—The cavity of the hind-brain becomes the fourth ventricle. By the time the ventral cephalic flexure appears the hind-brain exceeds in length the combined lengths of the other two brain vesicles. Anteriorly it exhibits a constriction, the *isthmus rhombencephali* (fig. 134, Isthmus), which is best seen when the brain is viewed from the dorsal aspect. From the isthmus the brachia conjunctiva of the cerebellum and the anterior medullary velum are formed. The rest of the hind-brain consists of two parts, an upper, the *metencephalon*, and a lower, the *myelencephalon*. The cerebellum is developed by a thickening of the roof, and the pons by a thickening of the floor and lateral walls of the metencephalon. The floor and lateral walls of the myelencephalon

are thickened to form the medulla oblongata ; its roof remains thin, and, retaining to a great extent its epithelial nature, is expanded in a lateral direction. Later, by the growth and backward extension of the cerebellum, the roof is folded inwards towards the cavity of the fourth ventricle ; it assists in completing the dorsal wall of this cavity, and is also invaginated to form the ependymal covering of the chorioid plexuses of the ventricle. Above it is continuous with the posterior medullary velum ; below, with the obex and ligulæ.

The development of the *medulla oblongata*, though resembling that of the medulla spinalis, exhibits one or two interesting modifications. At an early stage the myelencephalon consists of two lateral walls, connected across the middle line by floor- and roof-plates (figs. 135, 136). Each lateral wall consists of an alar and a basal lamina, separated by an internal furrow, the remains of which are represented in the adult brain by the sulcus limitans of the rhomboid fossa. The contained cavity is more or less triangular in section, the base being formed by the thin and greatly expanded roof-plate, the upper part of which ultimately forms the posterior medullary velum. Pear-shaped neuroblasts are developed in

FIG. 136.—A transverse section through the medulla oblongata of a human embryo. (After His.)



the alar and basal laminæ, and their narrow stalks are elongated to form the axis-cylinders of the nerve-fibres. Opposite the furrow or boundary between the alar and basal laminæ a bundle of nerve-fibres attaches itself to the outer surface of the alar lamina This is named the *tractus solitarius* (fig. 136), and is formed by the sensory fibres of the glossopharyngeal and vagus nerves. It is the homologue of the *oval bundle* seen in the medulla spinalis (p. 86), and, like it, is developed by an ingrowth of fibres from the ganglia of the neural crest. At first it is applied to the outer surface of the alar lamina, but is soon buried by the growth over it of the neighbouring parts. By the fifth week the dorsal part of the alar lamina bends in a lateral direction along its entire length to form what is termed the *rhombic lip* (figs. 136, 140). Within a few days this lip adheres to, and unites with, the outer surface of the main part of the alar lamina, and so covers in the tractus solitarius and also the spinal root of the trigeminal nerve.

Neuroblasts accumulate in the mantle layer ; those in the basal lamina correspond with the cells in the anterior grey column of the medulla spinalis, and, like them, give origin to motor nerve-fibres ; in the medulla oblongata the neuroblasts are arranged in groups or nuclei, instead of forming a continuous column as in the medulla spinalis. From the alar lamina and its rhombic lip, neuroblasts migrate into the basal lamina, where some are aggregated to form the olivary nuclei, while many send their axis-cylinders through the floor-plate to the opposite side, and thus constitute the rudiment of the raphe of the medulla oblongata. By means of this thickening of the ventral portion, the motor nuclei are buried deeply in the interior, and in the adult are found close to the rhomboid fossa. This is still

further accentuated: (*a*) by the development of the pyramids of the medulla oblongata, which are formed about the fourth month by the downgrowth of the cerebrospinal fasciculi; and (*b*) by the fibres which pass to and from the cerebellum.

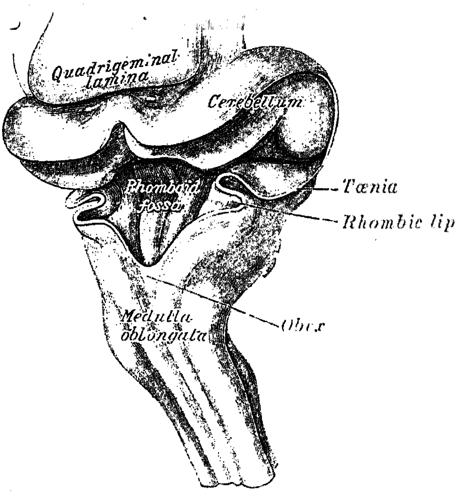
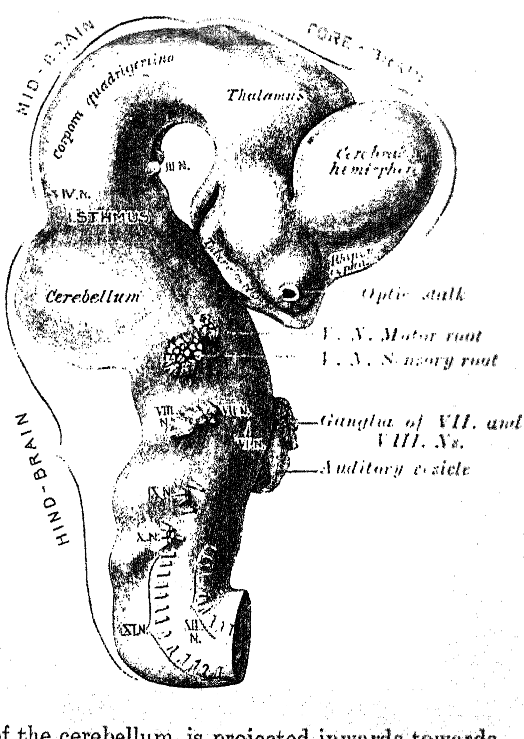


FIG. 137.—The hind-brain of a human embryo about three months old. Viewed from behind and partly from the right side. (From a model by His.)

The *pons* is developed from the ventrolateral wall of the metencephalon by a process similar to that which has been described for the ventrolateral wall of the medulla oblongata.

The *cerebellum* is developed in the roof of the anterior part of the hind-brain (figs. 137 to 142). The alar laminæ of this part increase in thickness and form two lateral plates which fuse in the middle line and produce a thick lamina which roofs the upper part of the cavity of the hind-brain vesicle; this lamina constitutes the rudiment of the cerebellum, the outer surface of which is originally smooth and convex. The flocculus and nodule are developed from the rhombic lip, and are recognisable as separate portions before any of the other cerebellar lobules. The fissures of the cerebellum appear first in the vermis and floccular region, and traces of them are found during the third month; the fissures on the cerebellar hemispheres do not appear till the fifth month. The primitive fissures are not developed in the order of their relative size in the adult—thus the horizontal sulcus at the fifth month is merely a shallow groove. The more important of the early fissures are: (*a*) the *fissura prima* between the developing culmen and clivus, and (*b*) the *fissura secunda* between the future pyramid and uvula. The groove produced by the bending over of the rhombic lip is here known as the *floccular fissure*; when the two lateral walls fuse, the right and left floccular fissures join in the middle line, and their central part becomes the *postnodular-fissure*.

FIG. 138.—The brain of a human embryo about four and a half weeks old. Right lateral aspect. (From a model by His.)

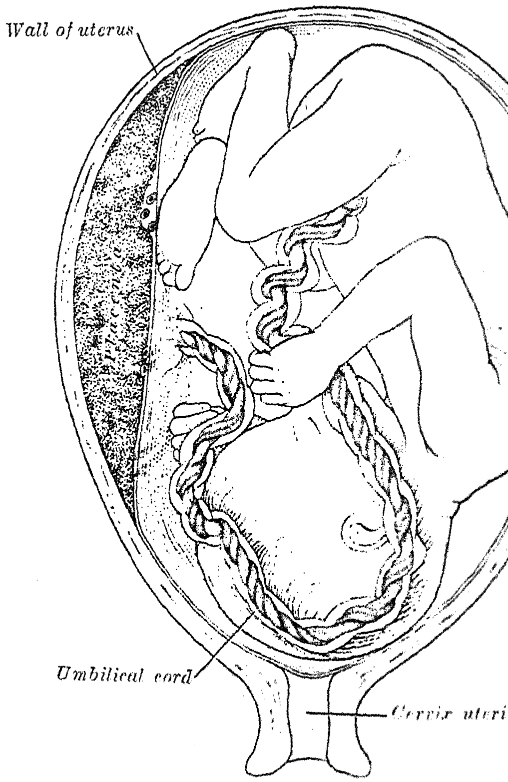


On the ventricular surface of the cerebellar lamina a transverse furrow, the *incisura fastigii*, appears and then deepens to form the tent-like recess of the roof of the fourth ventricle. The rudiment of the cerebellum at first projects in a dorsal direction; but, by the backward growth of the cerebrum, it is folded downwards, and somewhat flattened, and the thin roof-plate of the fourth ventricle, originally continuous with the posterior border of the cerebellum, is projected inwards towards the cavity of the ventricle.

the intervillous space, but these pillars do not extend as far as the chorion, except in the marginal part of the placenta; later they form the *placental septa* which incompletely divide the placenta into lobes or *cotyledons*.

Maternal blood is conveyed to the intervillous space by branches of the uterine arteries and carried away by tributaries of the uterine veins (figs. 101, 102). These vessels lose their muscular coats as they enter the basal plate, and in this plate consist of sinuous channels lined only with endothelium; these channels open into the intervillous space, the arteries ending near the placental septa and the veins beginning near the centres of the cotyledons. The endothelial lining of the uterine vessels ends where the vessels open into the intervillous space, the latter being lined throughout with syncytiotrophoblast. The circumferential part of the intervillous space

FIG. 101.—A fœtus in utero, between the fifth and sixth months.



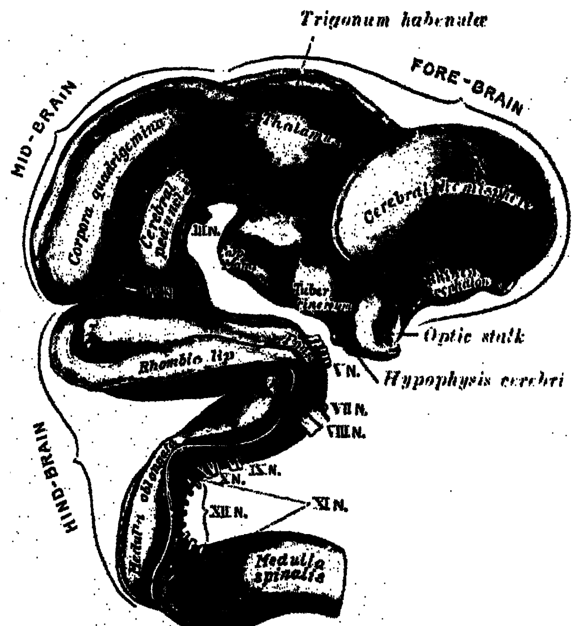
consists of an irregular channel named the *marginal sinus* (fig. 102): this sinus partly encircles the placenta and communicates peripherally with the uterine veins, and centrally with the intervillous space; clusters of placental villi project into it.

The fœtal and maternal blood-currents do not intermingle, being separated from each other by the delicate walls of the villi. Nevertheless, the fœtal blood is able to absorb, through the walls of the villi, oxygen and nutritive materials from the maternal blood, and give up to the latter its waste products. The blood, so purified, is carried back to the fœtus by the umbilical veins. It will thus be seen that the placenta not only establishes a mechanical connexion between the mother and the fœtus, but subserves for the latter the purposes of nutrition, respiration, and excretion. That the placenta possesses certain selective powers is evidenced by the fact that glucose is more plentiful in the maternal than in the fœtal blood; it is interesting to note also that the proportion of iron, lime and potash in the fœtus is increased during the last months of pregnancy. Further, there is evidence that the maternal leucocytes may migrate into the fœtal blood, since leucocytes are much more numerous in the blood of the umbilical vein than in that of the umbilical arteries.

Applied Anatomy.—The placenta is usually attached near the fundus uteri, and its site corresponds with that at which the ovum is imbedded. It may, however, occupy a lower

The *diencephalon*.—From the alar lamina of the diencephalon, the thalamus, metathalamus, and epithalamus are developed. The *thalamus* (figs. 138 to 142) arises as a thickening which involves the anterior two-thirds of the alar lamina. The two thalami are visible, for a time, on the surface of the brain, but are subsequently hidden by the cerebral hemispheres which grow backwards over them. The thalami extend medialwards and gradually narrow the interval between them into a slit-like cavity which forms the greater part of the third ventricle; their medial surfaces adhere, in part, to each other, and the *intermediate mass* of the ventricle is developed across the area of contact. The *metathalamus* comprises the medial and lateral geniculate bodies which originate as slight outward bulgings of the alar lamina. In the adult the lateral geniculate body appears as an eminence on the lateral part of the posterior end of the thalamus, while the medial lies under cover of the pulvinar

FIG. 140.—The brain of a human embryo, about five weeks old. Right lateral aspect; the roof of the hind-brain has been removed. (From a model by His.)



of the thalamus. The *epithalamus* includes the pineal body, the posterior commissure, and the trigonum habenulæ. The pineal body arises as a bilateral evagination of the roof-plate immediately in front of the mid-brain; only the left portion of this evagination persists in vertebrates, and it becomes solid with the exception of its proximal part, which forms the recessus pinealis. The pineal body consists essentially of (*a*) a distal part representing a rudimentary eye, and (*b*) a proximal part which is glandular in nature; only this latter portion is represented in man. The posterior commissure is formed by the ingrowth of fibres into the depression behind and below the pineal evagination, and the trigonum habenulæ is developed in front of the pineal recess.

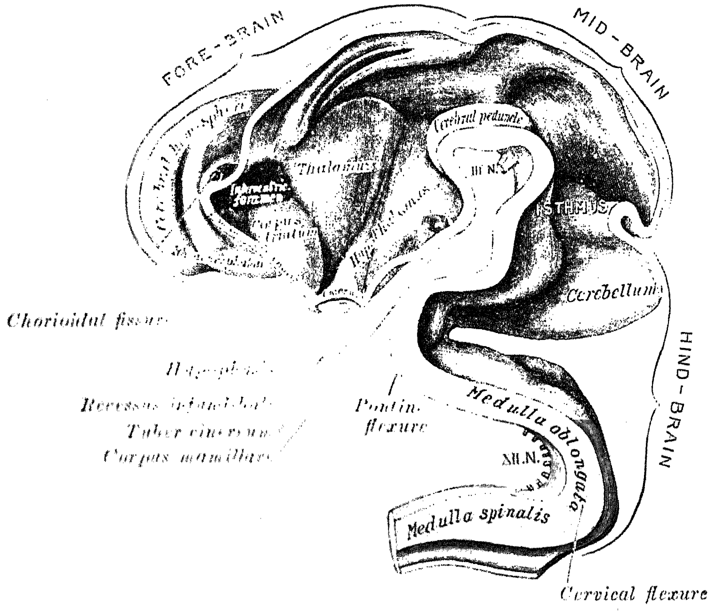
From the basal laminæ of the diencephalon the *pars mamillaris hypothalami* is developed; this comprises the corpora mamillaria and the posterior part of the tuber cinereum. The corpora mamillaria arise as a single thickening, which is divided by a median furrow during the third month.

The roof-plate of the diencephalon, in front of the pineal body, remains thin and epithelial in character, and is subsequently invaginated by the chorioid plexuses of the third ventricle.

The *telencephalon* consists of a median portion and two lateral diverticula. The median portion forms the anterior part of the cavity of the third ventricle, and is closed below and in front by the lamina terminalis. The lateral diverticula consist of outward pouchings of the alar laminæ; the cavities represent the future

lateral ventricles, and their walls the nervous matter of the cerebral hemispheres. The roof-plate of the telencephalon remains thin, and is continuous in front with the lamina terminalis, and behind with the roof-plate of the diencephalon. In the basal laminæ and floor-plate the *pars optica hypothalami* is developed; this comprises the anterior part of the tuber cinereum, the infundibulum and posterior lobe of the hypophysis, and the optic chiasma. The anterior part of the tuber cinereum is derived from the posterior part of the floor of the telencephalon; the infundibulum and posterior lobe of the hypophysis arise as a downward diverticulum from the floor. The most dependent part of the diverticulum becomes solid and forms the posterior lobe of the hypophysis; the anterior lobe of the hypophysis is developed from a diverticulum of the ectodermal lining of the stomodæum (p. 135). The optic chiasma is formed by the meeting and partial decussation of the optic nerves, which subsequently grow backwards as the optic tracts and end in the diencephalon.

FIG. 141.—The brain of a human embryo about five weeks old. Medial aspect of right half. The roof of the hind-brain has been removed. (From a model by His.)



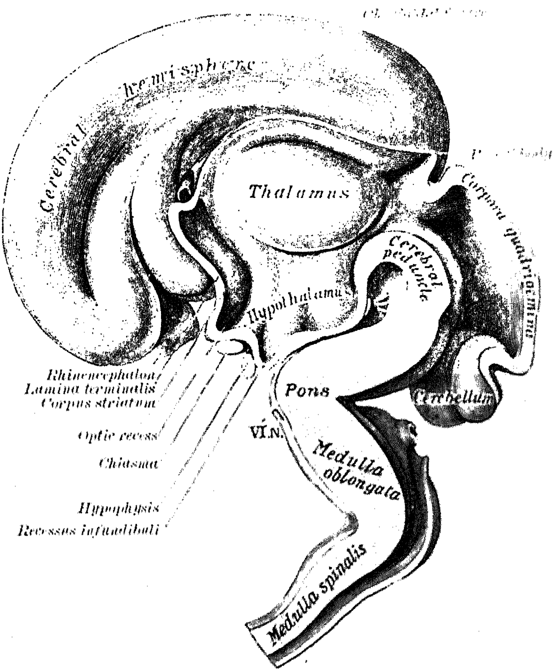
The *cerebral hemispheres* arise as diverticula of the alar laminæ of the telencephalon (figs. 138 to 142); they increase rapidly in size and ultimately overlap the structures developed from the mid- and hind-brains. This great expansion of the hemispheres is a characteristic feature of the brains of mammals, and attains its maximum development in the brain of man. G. Elliot Smith divides each cerebral hemisphere into three fundamental parts, viz. the rhinencephalon, the corpus striatum, and the neopallium.

The *rhinencephalon* (figs. 140 to 143) represents the oldest part of the telencephalon, and forms almost the whole of the hemisphere in fishes, amphibians, and reptiles. In man it is feebly developed in comparison with the rest of the hemisphere, and comprises the following parts, viz. the olfactory lobe (consisting of the olfactory tract and bulb, and the trigonum olfactorium), the anterior perforated substance, the septum pellucidum, the subcallosal, supracallosal, and dentate gyri, the fornix, the hippocampus, and the uncus. The rhinencephalon appears as a longitudinal elevation, with a corresponding internal groove, on the under surface of the hemisphere close to the lamina terminalis; it is separated from the lateral surface of the hemisphere by a furrow, the *external rhinal fissure*, and is continuous behind with that part of the hemisphere which will ultimately form the anterior end of the temporal lobe. The elevation is divided by a groove into an anterior and a posterior part. The anterior grows forward as a hollow stalk the lumen of which

is continuous with the anterior part of the lateral ventricle. During the third month the stalk becomes solid and forms the rudiment of the olfactory bulb and tract; a strand of gelatinous tissue in the interior of the bulb indicates the position of the original cavity. From the posterior part the anterior perforated substance and the pyriform lobe are developed; at the beginning of the fourth month the latter forms a curved elevation continuous behind with the medial surface of the temporal lobe, and consisting, from before backwards, of the gyrus olfactorius lateralis, gyrus ambiens, and gyrus semilunaris, parts which in the adult brain are represented by the lateral root of the olfactory tract and the uncus. The position and connexions of the remaining portions of the rhinencephalon are described with the anatomy of the brain.

The *corpus striatum* (figs. 139, 141) appears in the fourth week as a triangular thickening of the floor of the telencephalon between the optic recess and the inter-

FIG. 142.—The brain of a human embryo, about three months old. Medial aspect of right half. (From a model by His.)

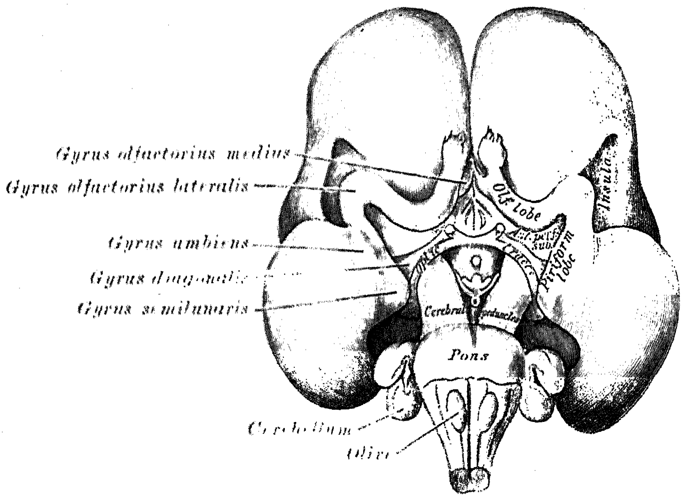


ventricular foramen, and continuous behind with the thalamic part of the diencephalon. It increases in size, and by the second month forms a swelling in the floor of the future lateral ventricle; this swelling reaches as far as the posterior end of the primitive hemisphere, and when this part of the hemisphere grows backwards and downwards to form the temporal lobe, the posterior part of the corpus striatum is carried into the roof of the inferior horn of the ventricle, where it is seen as the tail of the caudate nucleus in the adult brain. During the fourth and fifth months the corpus striatum becomes incompletely subdivided by the fibres of the internal capsule into two masses, an inner, the caudate nucleus, and an outer, the lentiform nucleus. In front, the corpus striatum is continuous with the anterior perforated substance; laterally it is confluent for a time with that portion of the wall of the vesicle which is developed into the insula, but this continuity is subsequently interrupted by the fibres of the external capsule.

The *neopallium* (fig. 144) forms the remaining, and by far the greater part of the cerebral hemisphere. It consists, at an early stage, of a relatively large, more or less hemispherical cavity—the primitive lateral ventricle—enclosed by a thin wall from which the cortex of the hemisphere is developed. The cavity expands in all directions, but more especially upwards and backwards, so that by the third month the hemispheres cover the diencephalon, by the sixth they overlap the mid-brain, and by the eighth the hind-brain.

The lamina terminalis unites the two hemispheres but does not share in their expansion, and thus the hemispheres are separated by a cleft, the forerunner of the longitudinal fissure, and this cleft is occupied by a septum of mesodermal tissue which constitutes the primitive falx cerebri. Coincidently with the expansion of the vesicle, its cavity is drawn out into three prolongations which represent the horns of the future lateral ventricle; the hinder end of the vesicle is carried downwards and forwards, and forms the inferior horn; the posterior horn is produced somewhat later, in association with the backward growth of the occipital lobe of the hemisphere. The roof-plate of the primitive fore-brain remains thin and of an epithelial character; it is invaginated into the lateral ventricle along the medial wall of the hemisphere. This invagination constitutes the chorioidal fissure, and extends from the interventricular foramen to the posterior end of the vesicle. Mesodermal tissue, continuous with that of the pia mater, and carrying blood-vessels with it, spreads between the two layers of the invaginated fold and forms the

FIG. 143.—The brain of an embryo at the beginning of the fourth month. Inferior aspect. (Kollmann.)



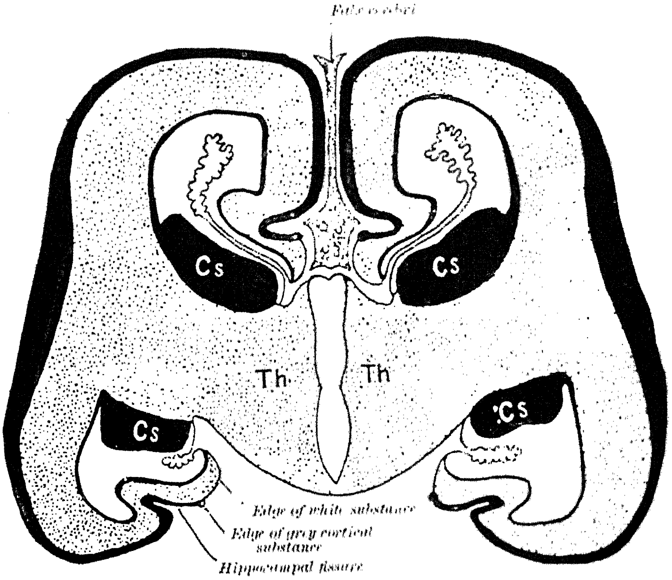
rudiment of the tela chorioidea; the margins of the tela become highly vascular and form the chorioid plexuses which for some months almost completely fill the ventricular cavities; the tela at the same time invaginates the epithelial roof of the diencephalon, and there forms the chorioid plexuses of the third ventricle. By the downward and forward growth of the posterior end of the vesicle to form the temporal lobe the chorioidal fissure finally reaches from the interventricular foramen to the extremity of the inferior horn of the ventricle.

Parallel with but above and in front of the chorioidal fissure the medial wall of the cerebral vesicle becomes folded and gives rise to a shallow fissure, the *hippocampal fissure*, on the medial surface, and to a corresponding bulging, the *hippocampus*, on the medial wall of the ventricular cavity.* The grey or ganglionic covering of the wall of the vesicle ends at the inferior margin of the fissure in a thickened edge; beneath this the marginal or reticular layer (future white substance) is exposed, and its lower thinned edge is continuous with the epithelial invagination covering the chorioid plexus (fig. 144). As a result of the later downward and forward growth of the temporal lobe the hippocampal fissure and the parts associated with it extend from the interventricular foramen to the end of the inferior horn of the ventricle. The thickened edge of grey substance becomes the gyrus dentatus, the fasciola cinerea and the supra- and sub-callosal gyri, while the free edge of the white substance forms the fimbria hippocampi and the body and crus of the fornix. The corpus callosum is developed within the

* Consult an article on the development of the fissura hippocampi by Marion Hines, *Journal of Comparative Neurology*, vol. 34, No. 1, February 1922.

arch of the hippocampal fissure, and the upper part of the fissure forms, in the adult brain, the callosal fissure on the medial surface of the hemisphere.

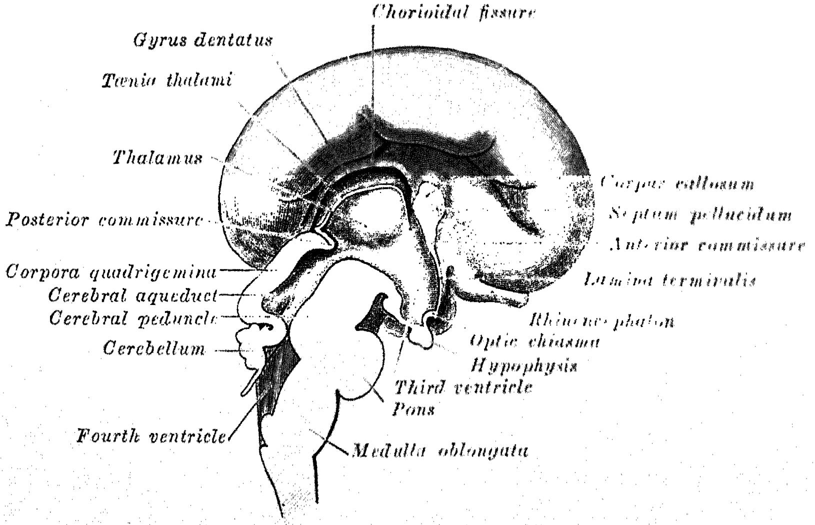
FIG. 144.—A coronal section through the brain to show the relations of the neopallium. Diagrammatic. (After His.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



Cs. Corpus striatum. Th. Thalamus.

The commissures (fig. 145).—The development of the posterior commissure has already been referred to (p. 94). The great commissures of the hemispheres, viz. the corpus callosum, the fornix, and the anterior commissure, arise from the lamina

FIG. 145.—The brain of a human embryo, four months old. Medial aspect of left half. (Marchand.)

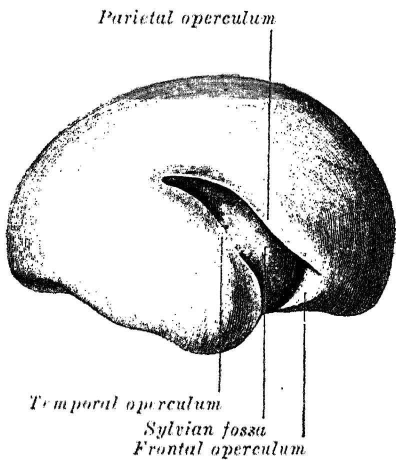


terminalis. About the fourth month a small thickening appears in this lamina, immediately in front of the interventricular foramen. The lower part of this

thickening is soon separated, and nerve-fibres appear in it to form the anterior commissure. The upper part continues to grow with the hemispheres, and is invaded by two sets of fibres. Transverse fibres, extending between the hemispheres, pass into its dorsal part, which is now differentiated as the corpus callosum. Into the ventral part longitudinal fibres from the hippocampus pass to the lamina terminalis, and through that structure to the corpora mamillaria; these fibres constitute the fornix. The *paraterminal bodies*, or portions of the rhinencephalon immediately in front of the lamina terminalis, are stretched to form the subcallosal gyrus and the laminæ of the septum pellucidum.

The *fissures or sulci*.—Until the fifth month the surface of the cerebral hemisphere is almost smooth. Between the sixth and seventh months the cortex increases rapidly in volume and becomes folded, and the surface is thus raised into a number of elevations or convolutions, separated by fissures or sulci; the chief of these are well developed by the seventh month. The *lateral cerebral, or Sylvian, fissure* differs from the others in its mode of development. About the third month a depression, the *Sylvian fossa*, appears on the lateral surface of the hemisphere (fig. 146): this fossa corresponds with the position of the corpus striatum, and its

Fig. 146.—The right cerebral hemisphere of a human embryo, about five months old. Lateral aspect.



floor is moulded to form the cortex of the insula. The intimate connexion which exists between the deep surface of the cortex of the insula and the corpus striatum prevents the insular part of the hemisphere wall from expanding at the same rate as the portions which surround it, with the result that the latter grow over and cover the insula, and constitute the temporal, parietal, frontal, and orbital opercula of the adult brain. The frontal and orbital opercula are the last to form, but by the end of the first year after birth the insula is completely submerged by the approximation of the opercula. The fissures separating the opposed margins of the opercula constitute the composite lateral cerebral fissure.

If a section across the wall of the hemisphere about the sixth week be examined microscopically it is seen to consist of a thin marginal or reticular layer, a thick ependymal layer, and a thin intervening mantle layer. Neuroblasts from the ependymal and mantle layers migrate into the deep part of the marginal layer and form the cells of the cerebral cortex. By the sixth month the middle cell-lamina has attained one-half, and the inner cell-lamina three-fourths of their adult thickness; the outer cell-lamina is the last to develop and its thickness varies with the intellectual capacity of the individual. The nerve-fibres which form the underlying white substance of the hemispheres consist at first of outgrowths from the cells of the corpora striata and thalami; the fibres from the cells of the cortex are added later. Medullation of these fibres begins about the time of birth and continues until puberty.

A summary of the parts derived from the cerebral vesicles is given in the following table :—

Rhombencephalon or hind-brain	1. Myelencephalon	Medulla oblongata. Lower part of fourth ventricle.
	2. Metencephalon	Pons. Cerebellum. Intermediate part of fourth ventricle.
	3. Isthmus rhombencephali	Anterior medullary velum. Brachia conjunctiva cerebelli. Upper part of fourth ventricle.
Mesencephalon or mid-brain		Cerebral peduncles. Lamina quadrigemina. Cerebral aqueduct.
Prosencephalon or fore-brain	1. Diencephalon	Thalamus. Metathalamus. Epithalamus. Pars mamillaris hypothalami. Posterior part of third ventricle.
	2. Telencephalon	Anterior part of third ventricle. Pars optica hypothalami. Cerebral hemispheres. Lateral ventricles. Interventricular foramen.

The **cerebral nerves.**—With the exception of the olfactory, optic, and acoustic nerves, which will be specially considered, the cerebral nerves are developed in a similar manner to the spinal nerves (p. 88). The sensory or afferent fibres of the trigeminal, facial, glossopharyngeal and vagus nerves are partly derived from the cells of the ganglion-rudiments of the neural crest and partly from the cells of certain thickened patches of the ectoderm (*placodes*), which are developed at the upper ends of the branchial grooves. The central processes of these cells form the roots of the nerves, the peripheral processes their fibres of distribution (fig. 133). It has been seen, in considering the development of the medulla oblongata (p. 91), that the *tractus solitarius* (fig. 148), derived from the ingrowing fibres from the cells of the ganglion-rudiments of the glossopharyngeal and vagus nerves, is the homologue of the *oval bundle* in the medulla spinalis which has its origin in the posterior nerve-roots. The motor nerves arise from the neuroblasts situated in the basal laminæ of the mid- and hind-brain. While, however, the spinal motor nerve-roots arise in one series from the basal lamina, the cerebral motor nerves are grouped into two sets, according as they spring from the medial or lateral parts of the basal lamina. To the former set belong the oculomotor, trochlear, abducent, and hypoglossal nerves ; to the latter, the accessory nerve, and the motor fibres of the trigeminal, facial, glossopharyngeal, and vagus nerves (figs. 147, 148).

The **sympathetic system.**—The ganglion-cells of the *sympathetic system* are derived from the segmented masses of the cells of the neural crests, which migrate along the sides of the neural tube to form the spinal ganglia ; certain cells detach themselves from the ventral margins of these masses and move towards the sides of the aorta, where some of them are grouped to form the ganglia of the sympathetic trunks, while others undergo a further migration and form the ganglia of the prevertebral and visceral plexuses. The ciliary, sphenopalatine, otic, and submaxillary ganglia are probably formed by groups of cells which have migrated from that part of the neural crest which gives rise to the semilunar ganglion.

The **chromaffin organs.**—The tissue from which the sympathetic ganglia are formed is at first a syncytium of cells termed sympathochromaffin cells, but later two varieties of cells, small and large, are differentiated from it ; the small cells (sympathoblasts) are transformed into the sympathetic nerve-cells, the large become chromaffin cells, and, separating from the others, accumulate to form the chromaffin organs. In the gangliated trunk of the sympathetic the chromaffin bodies are situated in depressions in the ganglia. In connexion with certain, but

not all, of the secondary plexuses of the sympathetic system chromaffin organs are found; the largest members of this series are the *aortic bodies*, which lie along the sides of the abdominal aorta between the superior mesenteric and common iliac arteries; to this group belong also the *carotid glomera* (carotid bodies). After birth the chromaffin organs degenerate and can no longer be isolated by gross dissection, but chromaffin tissue can be recognised with the microscope in the sites originally occupied by them.

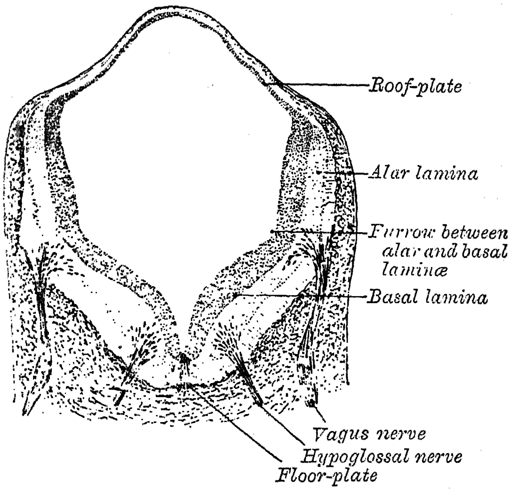


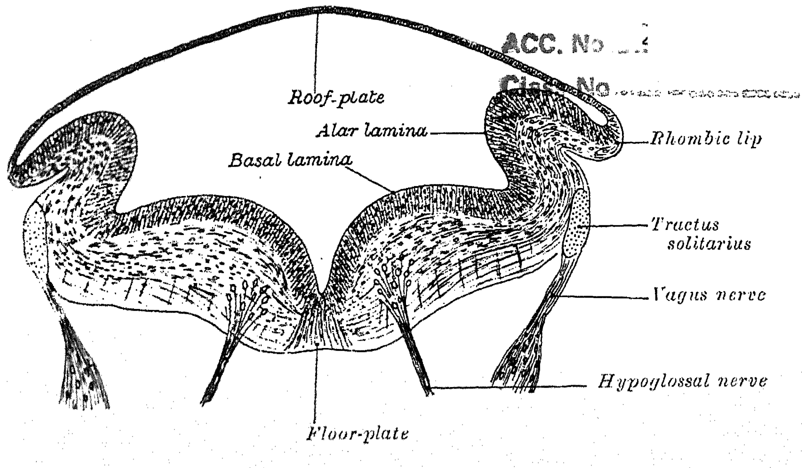
FIG. 147.—A transverse section through the medulla oblongata of a human embryo. × 32. (From Kollmann's Entwickelungsgeschichte.)

The **suprarenal glands.**—Each suprarenal gland consists of a cortical portion derived from the cœlomic epithelium and a medullary portion originally composed of sympathochromaffin tissue. The cortical portion is first recognisable about the beginning of the fourth week as a series of buds from the cœlomic cells at the root of the mesentery. Later it is completely separated from the cœlomic epithelium and forms a suprarenal ridge projecting into the cœlom between the mesonephros and the root of the mesentery. Into this cortical portion cells from the neighbouring masses of sympathochromaffin tissue migrate along the line of its central vein to form the medullary portion of the gland.

The **nose.**—The development of the nose has already been considered (pp. 78 to 81).

The *olfactory nerves* are developed from the cells of that part of the ectoderm which lines the olfactory pits; these cells undergo proliferation and give rise to what are termed the *olfactory cells* of the nose. The axons of these cells grow into the overlying olfactory bulb and form the olfactory nerves.

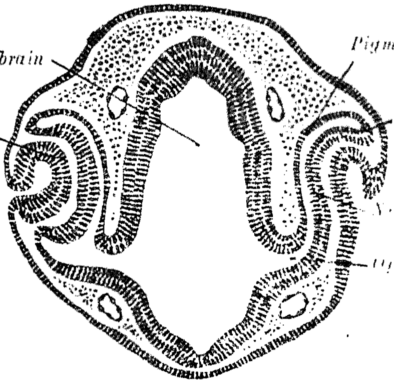
FIG. 148.—A transverse section through the medulla oblongata of a human embryo. (After His.)



The **eyes.**—The rudiments of the eyes appear as a pair of hollow diverticula from the lateral aspects of the fore-brain. These diverticula are visible before the closure of the anterior neuropore; after its closure they are known as the *optic vesicles*. They project towards the sides of the head, and the distal part of each

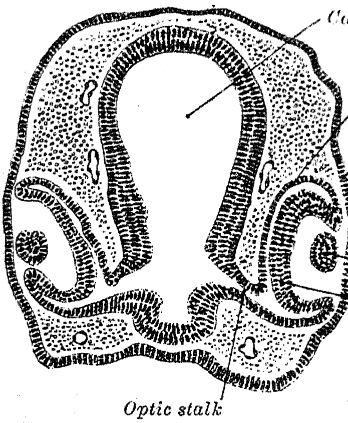
expands to form the *optic bulb*, while the proximal part remains narrow and constitutes the *optic stalk* (figs. 149, 150). A small area of ectoderm overlying the optic bulb becomes thickened, and ultimately separated as the *lens-vesicle*, or rudiment of the crystalline lens. The outer wall of the optic bulb increases in thickness and undergoes invagination so that the bulb is converted into a cup, the

FIG. 149.—A transverse section through the head of a chick, about forty-eight hours old. (From Duval's Atlas d'Embryologie.)



optic cup, consisting of two strata of cells (fig. 150). These two strata are continuous with each other at the cup-margin, which ultimately overlaps the front of the lens and reaches as far forward as the future aperture of the pupil. The invagination is not limited to the outer wall of the bulb, but involves also its postero-inferior surface and extends in the form of a groove for some distance along the optic stalk, and thus, for a time, a gap or fissure, the *chorioidal fissure*, exists in the lower part of the cup (fig. 151). Through the groove and fissure the mesoderm extends into the optic stalk and cup, and in this mesoderm an artery is developed ; during the seventh week the groove and fissure close, and the artery forms the central artery of the retina. Sometimes the chorioidal fissure persists, and when this occurs the chorioid and iris in the region of the fissure remain undeveloped, giving rise to the condition known as *congenital coloboma* of the chorioid or iris.

FIG. 150.—A transverse section through the head of a chick embryo, about fifty-two hours old. (From Duval's Atlas d'Embryologie.)

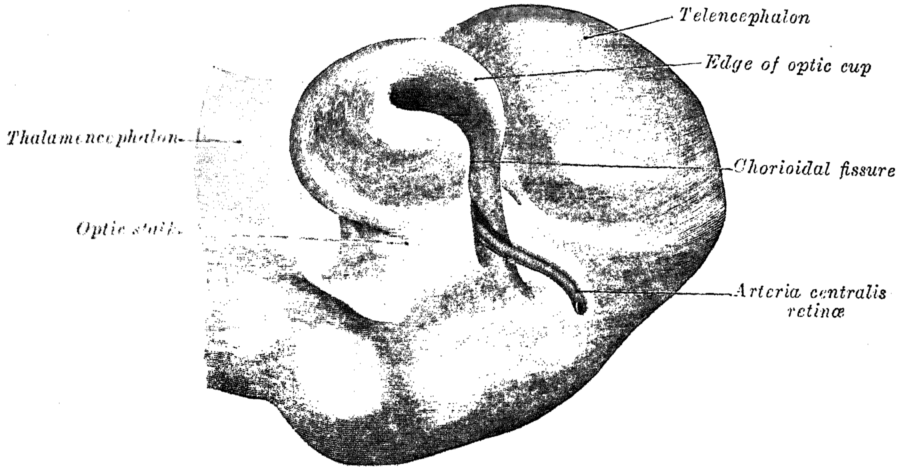


The retina is developed from the optic cup. The outer stratum of the cup persists as a single layer of cells which assume a columnar shape, acquire pigment, and form the pigmented layer of the retina, the pigment first appearing in the cells near the edge of the cup. The cells of the inner stratum proliferate and form a layer of considerable thickness from which the nervous elements and the sustentacular fibres of the retina, together with a portion of the vitreous body, are developed. In the portion of the cup which overlaps the lens the inner stratum is not differentiated into nervous elements, but persists as a layer of columnar cells which, together with the corresponding part of the pigmented layer, form the *pars ciliaris* and *pars iridica retinæ*.

The cells of the inner or retinal layer of the optic cup differentiate into spongioblasts and germinal cells, and the latter by their subdivisions give rise to neuroblasts. From

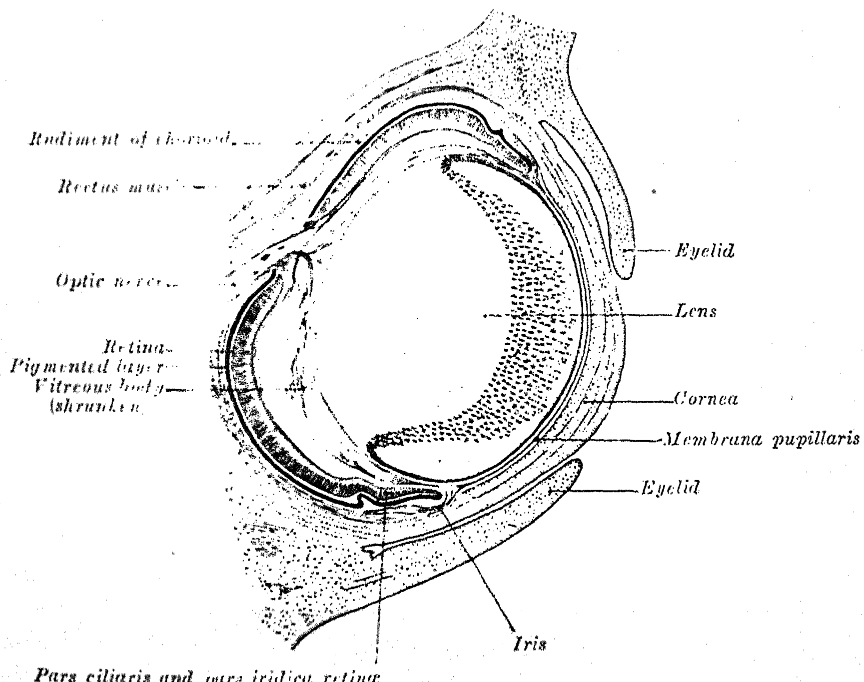
the spongioblasts the sustentacular fibres of Müller, the outer and inner limiting membranes, and the ground-work of the molecular layers of the retina, are formed. The neuroblasts become arranged to form the ganglionic and nuclear layers. The layer

FIG. 151.—The optic cup and the chorioidal fissure of a human embryo, about four weeks old. Ventral aspect. (Kollmann.)



of rods and cones is first developed in the central part of the optic cup, and from there gradually extends towards the cup margin. All the layers of the retina are completed by the eighth month of fœtal life.

FIG. 152.—A section through the eye of a rabbit embryo, about eighteen days old. × 30. (Kölliker.)

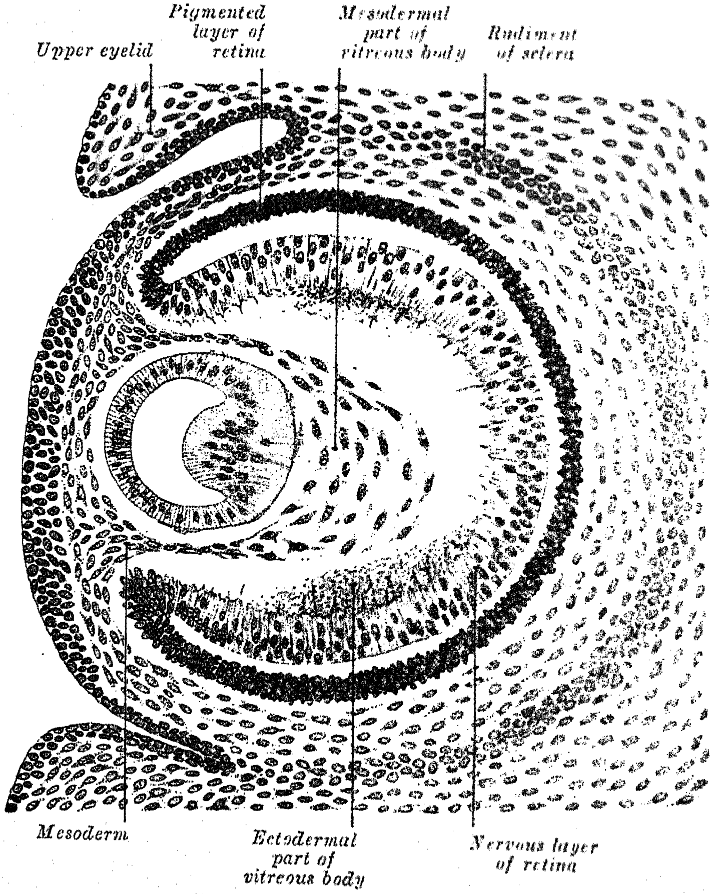


The optic stalk is converted into the optic nerve by the obliteration of its cavity and the growth of nerve-fibres into it. Most of these fibres are centripetal, and

are the axons of the nerve-cells of the ganglionic layer of the retina, but a few are centrifugal and are derived from nerve-cells in the brain. The fibres of the optic nerve receive their medullary sheaths about the tenth week after birth. The optic chiasma is formed by the meeting and partial decussation of the fibres of the two optic nerves. Behind the chiasma the fibres are continued backwards as the optic tracts to the thalami and mesencephalon.

The crystalline lens is developed from the lens-vesicle, which recedes within the margin of the cup, and becomes separated from the overlying ectoderm by mesoderm. The cells forming the posterior wall of the vesicle lengthen and are

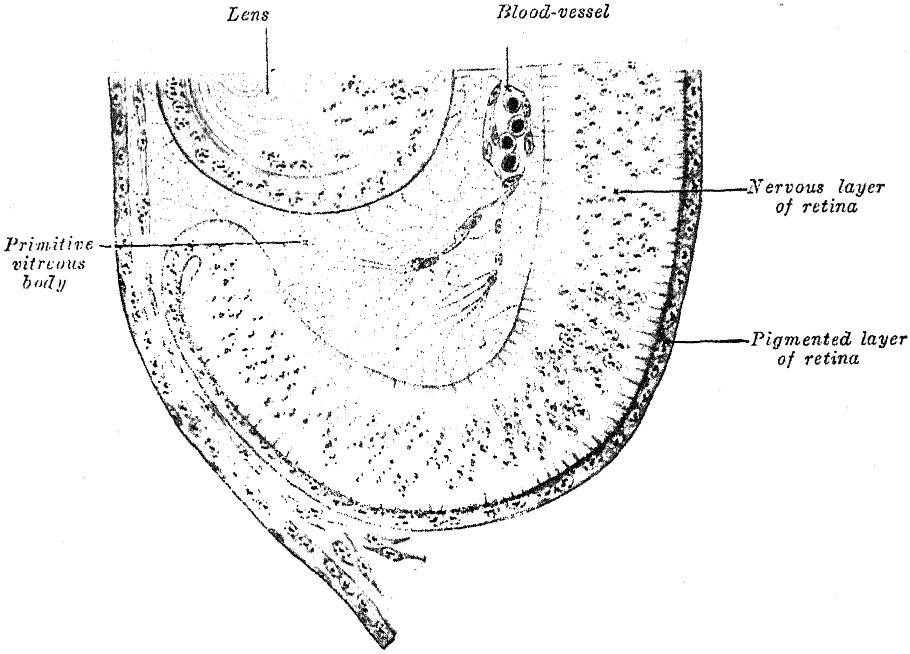
Fig. 153.—A sagittal section through the eye of a human embryo, about six weeks old. (Kollmann.)



converted into the lens-fibres, which grow forward and fill the cavity of the vesicle (fig. 152). The cells forming the anterior wall retain their cellular character, and form the epithelium on the anterior surface of the fully developed lens. By the second month the lens is invested by a vascular mesodermal capsule, the *capsula vasculosa lentis*, the anterior part of which, covering the front of the lens, is named the *pupillary membrane*; the blood-vessels supplying the posterior part of this capsule are derived from the hyaloid artery; those for the anterior part from the anterior ciliary arteries. By the sixth month all the vessels of the capsule are atrophied except the hyaloid artery, which disappears during the ninth month of fœtal life; after birth the position of this artery is indicated by the hyaloid canal, which reaches from the optic disc to the posterior surface of the lens. With the loss of its blood-vessels the capsula vasculosa lentis disappears, but sometimes the pupillary membrane persists at birth, giving rise to the condition termed *congenital atresia of the pupil*.

The vitreous body is developed between the lens and the optic cup. The lens-rudiment and the optic vesicle are at first in contact with each other, but after the closure of the lens-vesicle and the formation of the optic cup the former is withdrawn from the retinal layer of the cup; the two, however, remain connected by a network of delicate protoplasmic processes. This network, derived partly from the cells of the lens and partly from those of the retinal layer of the cup, constitutes the primitive vitreous body (figs. 153, 154). At first these protoplasmic processes spring from the whole of the retinal layer of the cup, but later are limited to the ciliary region, where by a process of condensation they appear to form the zonula ciliaris. The mesoderm which enters the cup through the chorioidal fissure and around the equator of the lens becomes intimately united with this reticular tissue, and contributes to form the vitreous body, which is therefore derived partly from the ectoderm and partly from the mesoderm.

FIG. 154.—A section through the developing eye of a trout. (Szily.)



The aqueous chamber of the eye appears as a cleft in that part of the mesoderm which intervenes between the lens and the ectoderm. The layer of mesoderm in front of the cleft forms the substantia propria of the cornea, that behind the cleft the stroma of the iris and the pupillary membrane. The fibres of the Ciliaris muscle are derived from the mesoderm, but those of the Sphincter and Dilatator pupillæ are of ectodermal origin, being developed from the cells of the pupillary part of the optic cup.

The sclera and chorioid are derived from the mesoderm surrounding the optic cup.

The eyelids are formed as small cutaneous folds (fig. 152). About the middle of the third month their edges come together and unite in front of the cornea; they remain united until about the end of the sixth month.

The epithelium of the alveoli and ducts of the lacrimal gland arise as a series of tubular buds from the ectoderm of the superior conjunctival fornix; these buds are arranged in two groups, one forming the superior or orbital, and the other the inferior or palpebral, part of the gland. The lacrimal sac and nasolacrimal duct result from a thickening of the ectoderm in the *naso-optic furrow* between the lateral nasal and maxillary processes (p. 79). This thickening forms a solid cord of cells which sinks into the mesoderm; during the third month the central cells of the cord break down, and a lumen, the naso-lacrimal duct, is established. The lacrimal ducts or canaliculi arise as buds from the upper part of the cord of cells and secondarily establish openings (puncta lacrimalia) on the margins of the lids; the

inferior duct cuts off a small part of the lower eyelid to form the caruncula lacrimalis (Ask). The epithelium of the cornea and conjunctiva is of ectodermal origin, as are also the eyelashes and the lining cells of the tarsal and other glands which open on the margins of the eyelids.

The ears.—The rudiments of the internal ears appear shortly after those of the eyes, as two patches of thickened, surface ectoderm, the *auditory plates*, over the region of the hind-brain. Each auditory plate is invaginated and converted into the *auditory pit* (fig. 155). The mouth of the pit is then closed, and a vesicle, the *auditory vesicle* or *otocyst*, is formed (fig. 156): from it the epithelial lining

FIG. 155.—A section through the hind-brain and auditory pits of a human embryo, about twelve days old. (Kollmann.)

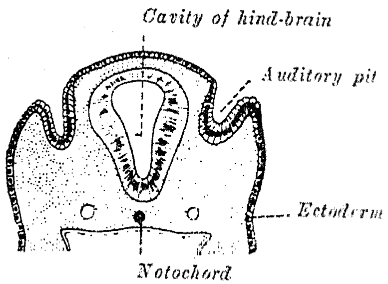


FIG. 156.—A section through the hind-brain and auditory vesicles of an embryo more advanced than that of fig. 155. (After His.)

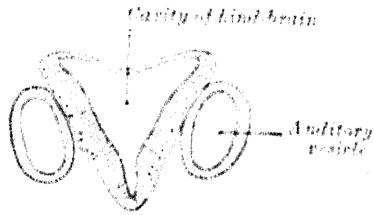


FIG. 157.—The left auditory vesicle of a human embryo, about four weeks old. Lateral aspect. (W. His, jun.)

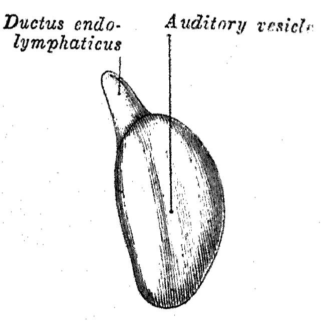
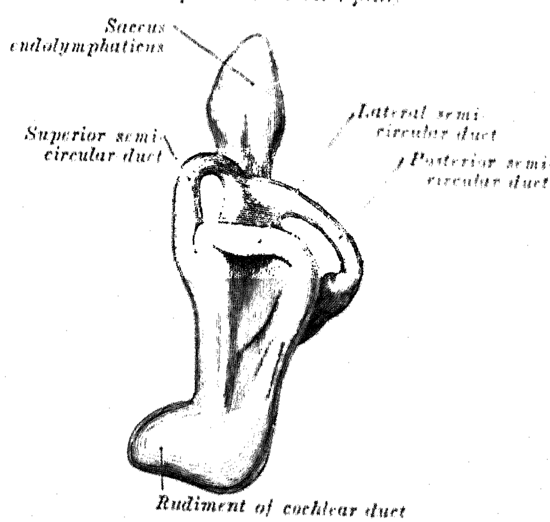


FIG. 158.—The left auditory vesicle of a human embryo, about five weeks old. Lateral aspect. (W. His, jun.)

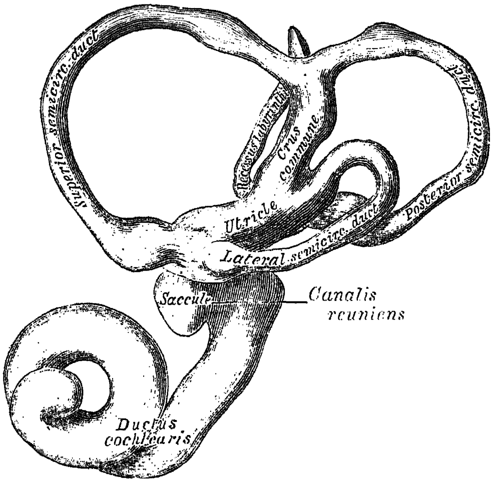


of the membranous labyrinth is derived. The vesicle assumes a flask-shape, and the neck of the flask is obliterated (fig. 157). From the vesicle certain diverticula are given off which form the various parts of the membranous labyrinth. One from the middle part forms the ductus and saccus endolymphaticus. A second, from the anterior end, elongates, and forms the coiled tube of the cochlear duct, the proximal or vestibular extremity of which is subsequently constricted to form the canalis reuniens. Three others appear as disc-like evaginations on the surface of the vesicle; the central parts of the walls of the discs coalesce and disappear, while the peripheral portions of the discs persist to form the semicircular ducts; the superior duct is the first, and the lateral the last, to be completed (fig. 158). The central part of the vesicle represents the membranous vestibule, and is subdivided by a constriction into a smaller ventral part, the saccule, and a larger dorsal and posterior part, the utricle (fig. 159). This subdivision is effected by a fold which extends deeply into the proximal part of the ductus endolymphaticus,

with the result that the utricle and saccule ultimately communicate with each other by means of a Y-shaped canal. The saccule opens into the cochlear duct, through the canalis reuniens; the semicircular ducts communicate with the utricle.

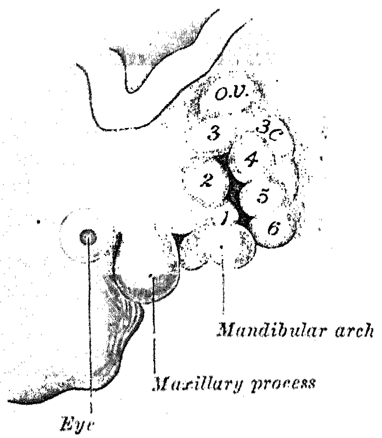
The mesoderm surrounding the various parts of the epithelial labyrinth is converted into a cartilaginous ear-capsule, and this is finally ossified to form the bony labyrinth. The portion of the capsule which envelopes the semicircular canals chondrifies before that which surrounds the cochlea. For a time the cartilaginous capsule is incomplete, and the cochlear, vestibular, and genicular ganglia are situated in the gap between its canalicular and cochlear parts. These ganglia are soon covered by an outgrowth of cartilage and at the same time the facial nerve is bridged by a growth of cartilage from the cochlear to the canalicular parts of the capsule. In the embryonic connective tissue between the cartilaginous capsule and the epithelial wall of the labyrinth the perilymphatic spaces are developed. Streeter * states that the rudiment of the vestibular perilymphatic space, or *periotic cistern* as he suggests this space should be named, can be seen in an embryo of from 30 to 40 mm. in length, in the reticulum between the saccule and the fenestra vestibuli. The scala tympani is next developed, and begins opposite the fenestra cochleæ; the scala vestibuli is the last to appear. The two scalæ gradually extend along either side of the ductus cochlearis and when they reach its tip, an opening which represents the helicotrema, is developed between them. The modiolus and the osseous spiral lamina of the cochlea are not preformed in cartilage but are ossified directly from connective tissue.

Fig. 159.—The left membranous labyrinth of a human embryo, 30 mm. long. (From a model by W. His, jun.)



The auditory tube and tympanic cavity were formerly regarded as being derived from the first pharyngeal pouch, but Frazer † has recently pointed out that they are developed from a recess, the *tubotympanic recess*, between the first and third visceral arches, the floor of the recess consisting of the first and second arches and the first and second pharyngeal pouches. By the forward growth of the third arch the inner part of the recess is narrowed to form the tubal region, and the inner part of the second arch is excluded from this portion of the floor. The outer part of the recess is subsequently developed into the tympanic cavity, and the floor of this part forms the outer wall of the tympanic cavity up to about the level of the chorda tympani nerve. From this it will be seen that the outer wall of the tympanic cavity 'has both first and second arch elements in it, the share taken by the first arch being limited to the part in front of the handle of the malleus. The

Fig. 160.—The tubercles from which the different parts of the auricula are developed. (His.)



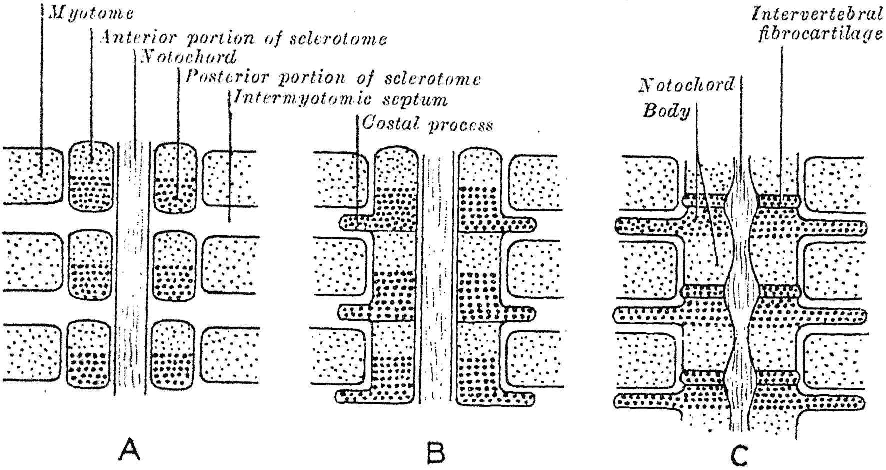
1, 2. Tubercles on mandibular arch. 3. Tubercle above groove. 3, *c*. Prolongation of 3 downwards. 4, 5, 6. Tubercles on hyoid arch. *o.v.* Auditory vesicle.

* George L. Streeter, *American Journal of Anatomy*, vol. xxi.

† J. Ernest Frazer, *Journal of Anatomy and Physiology*, vol. xlviii.

and ventrally; the dorsal extensions surround the neural tube and represent the future vertebral arch, while the ventral extend into the body-wall as the costal processes. The hinder part of the posterior mass joins the anterior mass of the succeeding sclerotome to form the vertebral body. Each vertebral body is therefore

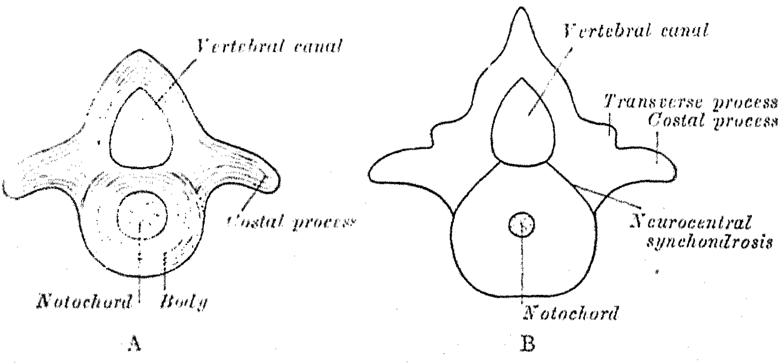
Fig. 104.—A scheme showing the manner in which each vertebral body is developed from portions of two adjacent segments.



a composite of two segments, being formed from the posterior portion of one and the anterior part of that immediately behind it. The vertebral and costal arches are derivatives of the posterior part of the segment in front of the intersegmental septum with which they are associated.

This stage is succeeded by that of the *cartilaginous vertebral column*. In the fourth week cartilaginous centres make their appearance on either side of the notochord; these extend round the notochord and form the bodies of the cartilaginous vertebræ. A pair of cartilaginous foci appear in the lateral parts of each vertebral arch, and grow backwards on either side of the neural tube to form the cartilaginous vertebral arch, and a separate cartilaginous centre appears for each costal process. In the eighth week the cartilaginous vertebral arch fuses with the

Fig. 105.—Diagrams showing (A) the membranous and (B) the cartilaginous stages of a typical vertebra.



cartilaginous body, and in the fourth month the halves of the arch unite on the dorsal aspect of the neural tube (fig. 105, B); the spinous process is developed from the junction of the halves of the vertebral arch. The transverse processes grow out from the vertebral arch behind the costal processes.

In the upper cervical vertebræ a band of mesodermal tissue, named the *hypochordal bar* (fig. 106, A), connects the ventral ends of each vertebral arch across the ventral surface of the intervertebral fibrocartilage. In all except the atlas or first cervical vertebra this bar is transitory and fuses with the intervertebral fibro-

of the auditory vesicle. The acoustic ganglion divides into the vestibular ganglion and the spiral ganglion of the cochlea; their nerve-cells are bipolar, each sending a proximal fibre into the neural tube, and a distal fibre to the epithelial cells of the auditory vesicle.

THE DEVELOPMENT OF THE VASCULAR SYSTEM

The blood-corpuscles and the blood-vessels first make their appearance between the entoderm and the mesoderm in three regions, viz.: (*a*) on the surface of the yolk-sac, (*b*) in the body-stalk, and (*c*) in the chorion.* The cells become arranged into solid strands or cords, which collectively form what His termed the *angioblast*. These strands join to form a close-meshed network, the *area vasculosa*, which covers the entire yolk-sac. The peripheral cells of the strands become flattened and joined to each other by their edges to form the endothelium of the walls of the primitive blood-vessels. Fluid collects within the strands and converts them into tubes, and the more centrally situated cells of the strands are thus pushed to the sides of the vessels and appear as masses of loosely-arranged cells projecting towards the lumen of the tube. These masses are termed *blood-islands* (figs. 163, 164); their cells are detached to form the primary blood-corpuscles (mesamœboids of Minot). The earliest blood-vessels, therefore, are formed at several separate centres; from the walls of these vessels buds grow out, become vascularised and converted into new vessels, and join with those of neighbouring areas to form a close meshwork. Wang † maintains that in the ferret embryo there is evidence to show that the origins of the blood-corpuscles and the endothelium of the blood-vessels are separate and distinct—the blood-corpuscles arising from the entoderm, and the vascular endothelium from the mesoderm; the blood-corpuscles are engulfed by the endothelium of the growing vessels and in this way enter their lumina. His was of opinion that the vessels within the embryo were developed as extensions of this network, but probably they arise independently. Most observers agree that, after the aortæ have appeared, no other independent vessels are laid down, i.e. all new vessels are derived from pre-existing ones.

FIG. 163.—A section through the vascular area to show the differentiation of the primitive vascular cells. Diagrammatic.

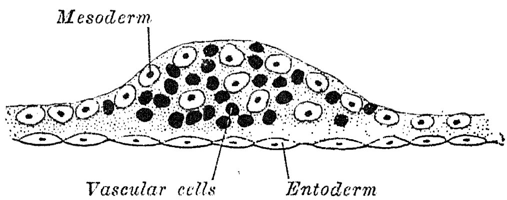
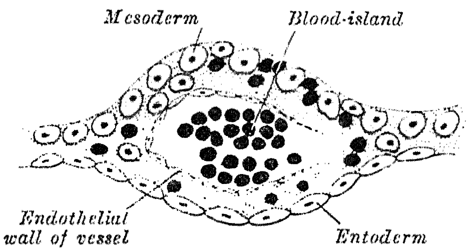


FIG. 164.—A section through a developing blood-vessel. Diagrammatic.



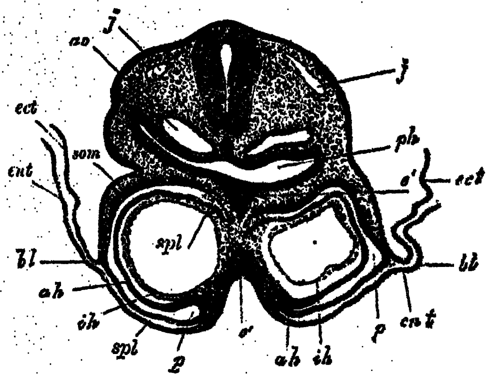
The red and the colourless corpuscles of the blood are derived from the *mesamœboids*. The earliest blood-corpuscles are thus all nucleated; they are also capable of subdivision and of executing amœboid movements. Some mesamœboids acquire colouring matter (hæmoglobin); their nuclei disintegrate and are extruded, and the non-nucleated red corpuscles or erythrocytes result. Other mesamœboids retain their nuclei; some remain in the blood as the leucocytes; others wander out into the tissues, particularly into the liver, the lymphoid tissues, and the marrow of the bones, where they form specialised collections from which the corpuscles of the blood are regenerated. From the mesamœboids five chief forms

* Consult an article "On the earliest blood-vessels in Man" by J. L. Bremer in the *Anatomical Record*, vol. viii. Feb. 1914.

† Chung-Ching Wang, *Journal of Anatomy*, vol. lii. parts 1 and 2.

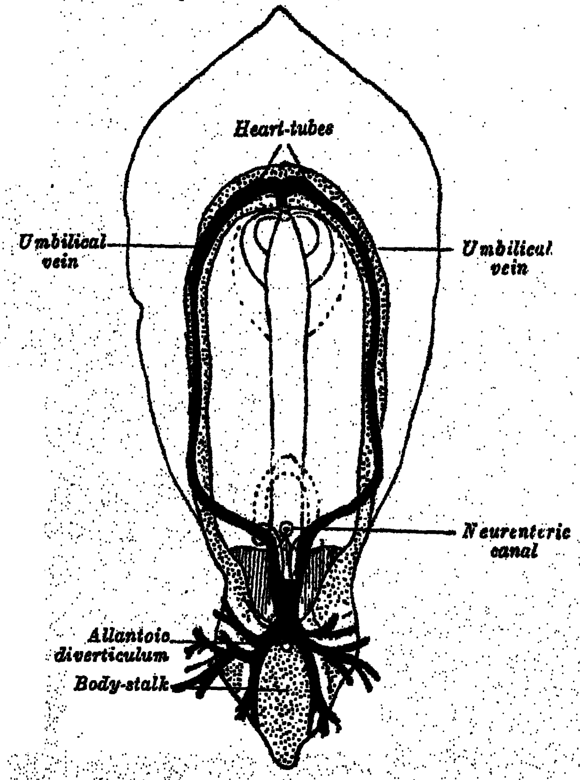
are derived: (1) erythrocytes, (2) lymphocytes, (3) finely granular or neutrophil leucocytes, (4) coarsely granular or eosinophil leucocytes, (5) degenerating or basiphil leucocytes (p. 28).

FIG. 165.—A transverse section through the region of the heart of a rabbit embryo, nine days old. × 80. (Kölliker.)



ah. Outer wall of heart. *ao.* Aorta. *bl.* Proamnion. *e'.* Septum between heart-tubes. *ect.* Ectoderm. *ent.* Entoderm. *ih.* Endothelial lining of heart. *j, j.* Jugular veins. *p.* Pericardium. *ph.* Pharynx. *som.* Somatopleure. *spl.* Splanchnopleure.

FIG. 166.—A diagram of the vascular channels in a human embryo of the second week. (After Eternod.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



The red lines are the dorsal aortæ continued into the umbilical arteries. The red dotted lines are the ventral aortæ, and the blue dotted lines the vitelline veins.

Minot describes three stages in the development of the red blood-corpuscles:—(*a*) *the ichthyoid blood-cells* containing granular nuclei, and representing the permanent blood-cells of fishes; (*b*) the *sauroid blood-cells* derived from but smaller than the former; they represent the permanent blood-cells of reptiles, and their nuclei contain a dense network of chromatin which stains very deeply; (*c*) the *blood-plastids* or early red blood-corpuscles which are at first spherical in shape; they are non-nucleated and found only in mammals.

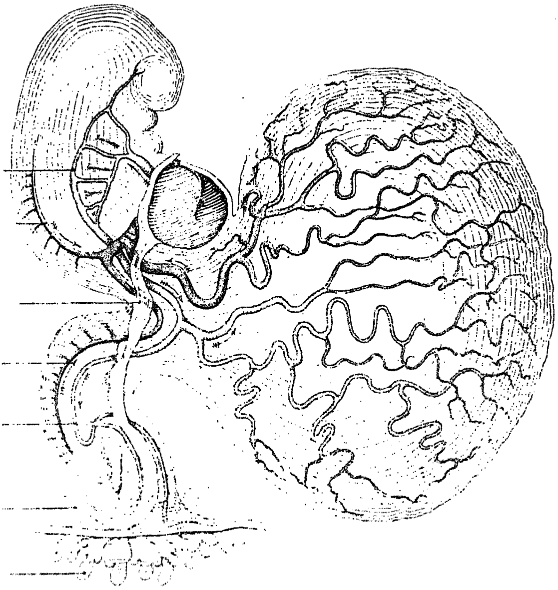
The earliest stages of the development of the human heart and blood-vessels have not yet been seen, but it may be assumed that they are similar to those occurring in other mammals. As already stated (p. 109), blood-vessels are first developed in the wall of the yolk-sac, and in the body-stalk and chorion, and it is still a matter of doubt whether the blood-vessels within the embryo arise as extensions from those of the yolk-sac (His), or are developed from vascular cells *in situ*, and subsequently establish connexions with those of extra-embryonic origin.

The first rudiment of the heart appears in the form of a pair of tubular vessels (primitive aortæ) which are developed from a mass of cells in the splanchnopleure of the pericardial area (fig. 165). These two vessels run backwards, one on either side of the notochord, and pass into the body-stalk along which they are carried as the umbilical arteries to the chorion.

By the forward growth and flexure of the head the pericardial area and the anterior portions of the primitive aortæ are folded under the head and come to lie on the ventral aspect of the fore-gut,

and each vessel now consists of a ventral and a dorsal part united by an arch; these three parts are named respectively the ventral aorta, the dorsal aorta, and the first aortic arch. The first aortic arches pass through the mandibular arches,

FIG. 167.—A human embryo, about fourteen days old, with yolk-sac. (After His.)



and behind them five additional pairs subsequently develop, so that altogether six pairs of aortic arches are formed.

In the pericardial region the two primitive aortæ, which from the first lie close together, come into contact and the partition between them disappears, and thus a single tubular heart is formed (fig. 168); from the cephalic end of the heart the ventral aortæ arise and into its caudal end the umbilical and vitelline veins pour their contents.

FIG. 168.—The head of a chick embryo, about thirty-eight hours old. Ventral aspect. × 26. (From Duval's Atlas d'Embryologie.)

Eternod * described the circulation in a human embryo which measured 1·3 mm. in length and was devoid of mesodermal somites (fig. 166). The rudiment of the heart was situated immediately below the fore-gut and consisted of a short stem.

* *Anat. Anzeiger*, Bd. xv. 1899.

It gave off two vessels, the primitive aortæ, which ran backwards, one on either side of the rudiment of the notochord, and then passed into the body-stalk, along which they were carried to the villi of the chorion. From the chorionic villi the blood was returned by a pair of umbilical veins which united in the body-stalk to form a single vein (vena umbilicalis impar); on reaching the embryo this vein

FIG. 169.—The heart of an early embryo, to illustrate its simple tubular condition. (From an Ecker-Ziegler model.)

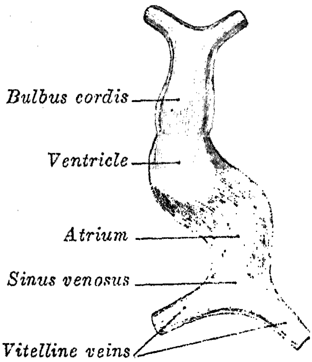
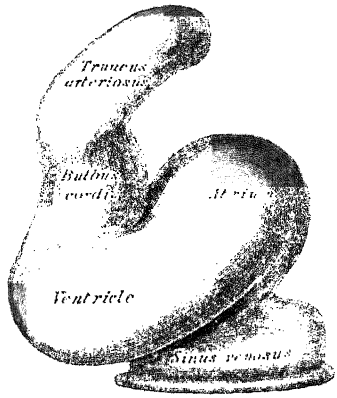
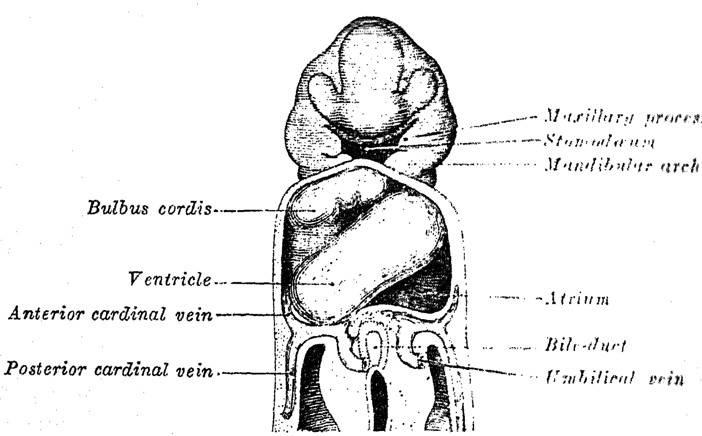


FIG. 170.—The heart of a human embryo, about fourteen days old. (From a model by His.)



divided into two which encircled the mouth of the yolk-sac and opened into the heart. At the junction of the yolk-sac and body-stalk each vein was joined by a transitory vitelline vein from the vascular plexus of the yolk-sac. The transitory vitelline veins are replaced by the true vitelline veins which return the blood from the yolk-sac, and enter the embryo through the anterior wall of the umbilical orifice (figs. 167, 168). They then traverse the septum transversum, a band of mesoderm which lies between the pericardium and the yolk-sac; in this septum each vitelline vein unites with the corresponding umbilical vein to form the *common*

FIG. 171.—The heart of a human embryo, about fifteen days old. (From a reconstruction by His.)

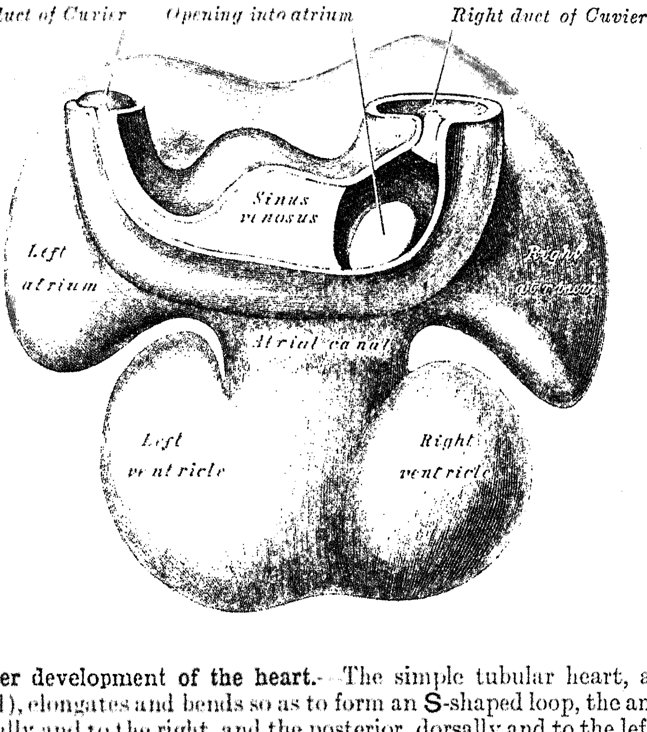


vitello-umbilical vein which opens into the caudal end (sinus venosus) of the tubular heart. The vitello-umbilical veins are soon joined by a pair of anterior cardinal (primitive jugular) veins from the head, and a little later each anterior cardinal vein is joined by a posterior cardinal vein from the trunk and limbs, and the short trunk (duct of Cuvier) formed by the union of these two veins opens into the corresponding

vitello-umbilical vein. The sinus venosus expands in a transverse direction and incorporates the adjoining parts of the vitello-umbilical veins which come to form the right and left horns of the sinus; into the horns of the sinus the three venous trunks, viz. the vitelline vein, the umbilical vein and the duct of Cuvier, open. The liver is developed in the septum transversum, and in the course of its development the vitelline and umbilical veins undergo important transformations which will be explained later (p. 121).

With the atrophy of the yolk-sac the vitelline circulation diminishes and ultimately ceases, and an increasing amount of blood is carried through the umbilical arteries to the villi of the chorion. Subsequently, as the non-placental chorionic villi atrophy, their vessels disappear; and then the umbilical arteries convey the whole of the blood from the embryo to the placenta, whence it is returned to the embryo by the umbilical veins.

FIG. 172.—The heart of a human embryo, about thirty-five days old. Dorsal aspect. (From a model by His.)

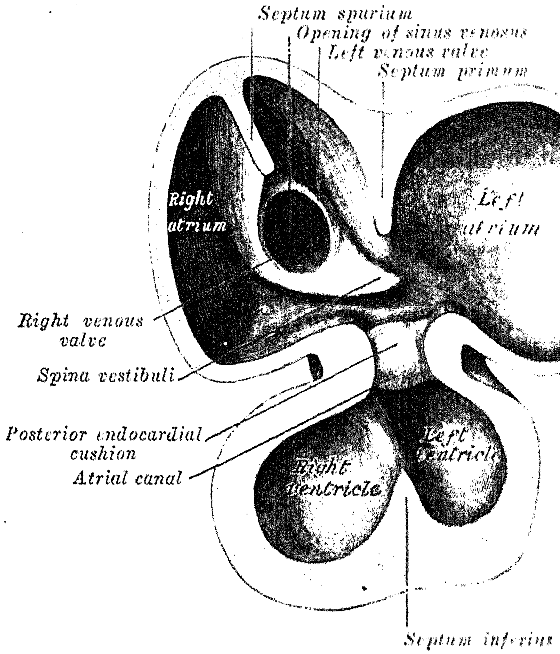


The **further development of the heart.**—The simple tubular heart, already described (p. 111), elongates and bends so as to form an S-shaped loop, the anterior part convex ventrally and to the right, and the posterior, dorsally and to the left (fig. 170). The intermediate portion arches transversely from left to right, and then turns sharply forward into the anterior part of the loop. Slight constrictions make their appearance in the tube and divide it from behind forwards into five parts, viz.: (1) the *sinus venosus*; (2) the *atrium*; (3) the *ventricle*; (4) the *bulbus cordis*, and (5) the *truncus arteriosus* (fig. 170). The constriction between the atrium and ventricle constitutes the *atrial canal* (fig. 172), and indicates the site of the future atrioventricular valves.

The sinus venosus is situated in the septum transversum behind the atrium, and opens into the latter by a median aperture. The sinus is at first placed transversely but soon assumes an oblique position and a crescentic shape (fig. 172); its right half or horn increases in size more rapidly than its left, and the sinus opens into the right portion of the atrium. The right horn of the sinus is ultimately incorporated with and forms a part of the right atrium, the line of union between it and the auricula being indicated in the interior of the adult atrium by a vertical crest, the *crista terminalis* of His. The left horn, which ultimately receives only the left duct of Cuvier, persists as the coronary sinus (fig. 172). The vitelline and umbilical veins are later replaced by a single vessel, the inferior vena cava, and the

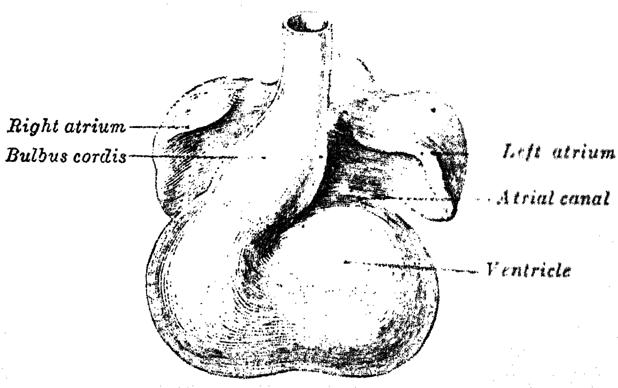
three veins (inferior vena cava and right and left ducts of Cuvier) open into the dorsal part of the atrium by a common slit-like aperture (fig. 173). The upper part of this aperture represents the opening of the permanent superior vena cava, the

FIG. 173.—The heart of a human embryo, about thirty days old. The interior of the dorsal half. (From a model by His.)



lower that of the inferior vena cava, and the intermediate part the orifice of the coronary sinus. The slit-like aperture lies obliquely, and is guarded by two valves, the *right* and *left venous valves* ; above the opening these unite with each other and are continuous with a fold named the *septum spurium* ; below the opening they fuse to form a triangular thickening—the *spina vestibuli*. The right venous valve is retained ; its cephalic portion, together with the septum spurium, forms the crista terminalis already mentioned. A small septum, the *sinus septum*, grows from

FIG. 174.—A heart showing the expansion of the atria. (From an Ecker-Ziegler model.)

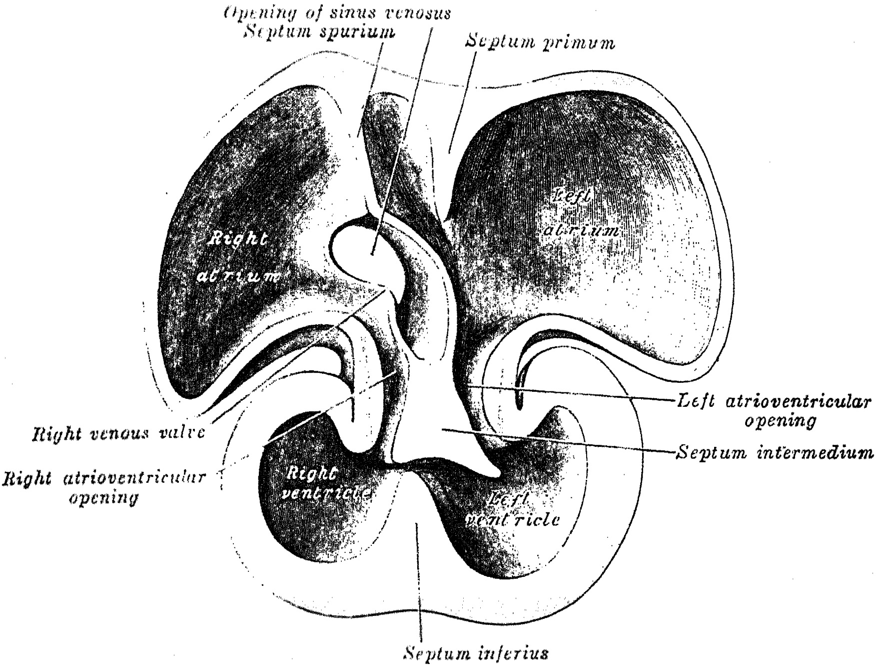


the posterior wall of the sinus venosus to fuse with the right venous valve and divide its caudal portion into two parts—an upper, the valve of the inferior vena cava, and a lower, the valve of the coronary sinus. The upper and middle thirds

of the left venous valve disappear; the lower one-third is continued into the spina vestibuli, and later fuses with the septum secundum of the atria and takes part in the formation of the limbus fossæ ovalis.

The atrial canal is at first a short straight tube connecting the atrial with the ventricular portion of the heart, but its growth being relatively slow, it is gradually overlapped by the atria and ventricles so that its position on the surface of the heart is indicated only by an annular constriction (fig. 174). Its lumen is reduced to a transverse slit, and two thickenings, or *endocardial cushions* (fig. 173), appear, one on its dorsal, and the other on its ventral wall. These endocardial cushions project into the atrial canal, and, meeting in the middle line, unite to form the *septum intermedium*, which divides the canal into two channels, the future right and left atrioventricular orifices.

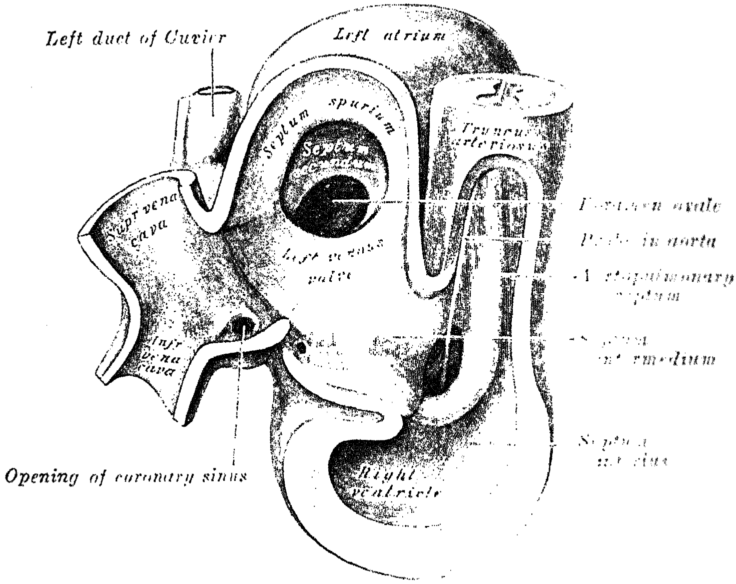
FIG. 175.—The heart of a human embryo, about thirty-five days old. The interior of the dorsal half. (From a model by His.)



The atrium grows rapidly, and by its lateral expansion partially encircles the bulbus cordis. The latter thus comes to lie in a groove which is the first indication of the ultimate division of the atrium into right and left chambers, the division being effected by a septum, the *septum primum* (figs. 173, 175), which grows from the dorsal to the ventral wall of the cavity. For a time the atria communicate with each other by an opening, the ostium primum of Born, in front of the free margin of the septum primum. This opening is closed by the union of the septum primum with the septum intermedium, but before this closure occurs a new opening is developed in the dorsal part of the septum primum; this new opening is known as the foramen ovale (ostium secundum of Born) and persists until birth. A crescentic septum, the *septum secundum* (fig. 176), grows from the upper and dorsal wall of the atrium immediately to the right of the septum primum and foramen ovale. The horns of this crescentic septum fuse with the ventral part of the septum primum, and the intervening free part of the septum secundum overlaps the foramen ovale and septum primum; the dorsal part of the latter septum acts as a flap-like valve which allows the blood to flow from the right into the left atrium, but not in an opposite direction. After birth, the free edge of the septum secundum blends with the septum primum and the foramen ovale is closed; sometimes the fusion is incomplete and the upper part of the foramen remains patent.

Issuing from either lung is a pair of pulmonary veins which unite to form a single vein, and these in turn join with one another to form a common trunk which opens into the left atrium. Subsequently the common trunk and the two veins

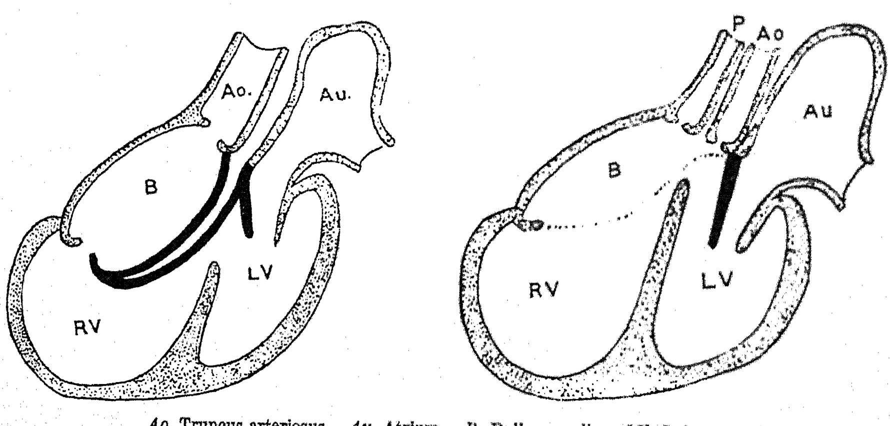
FIG. 176.—The heart of a human embryo, about thirty-five days old. Opened on right side. (From a model by His.)



forming it expand and form the vestibule or greater part of the left atrium, the expansion reaching as far as the orifices of the four veins which thus open separately into the adult left atrium.

The ventricle is divided by a septum, the *septum inferius* or *ventricular septum* (figs. 173, 175, 176), which grows upwards from the lower part of the ventricle, its position on the surface of the heart being indicated later by the interventricular

FIG. 177.—Diagrams to illustrate the transformation of the bulbus cordis. (Keith.)

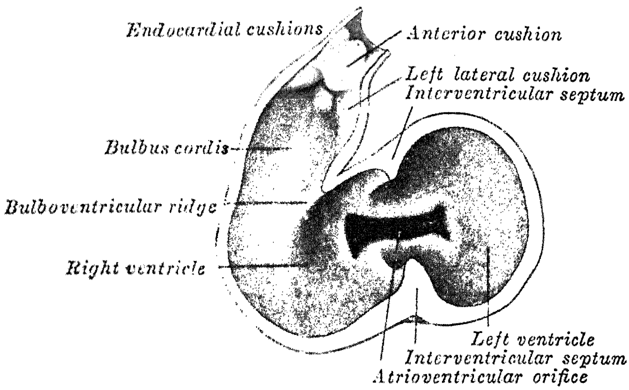


Ao. Truncus arteriosus. *Au.* Atrium. *B.* Bulbus cordis. *LV.* Left ventricle. *P.* Pulmonary artery. *RV.* Right ventricle.

sulcus. Its dorsal part increases more rapidly than its ventral portion, and fuses with the dorsal endocardial cushion. Above its ventral portion there exists for a time an interventricular foramen (fig. 176).

When the heart assumes its S-shaped form the bulbus cordis lies in front of and ventral to the ventricle. The adjacent walls of the bulbus cordis and ventricle approximate and fuse, and the fused portion projects as a ridge, the *bulboventricular ridge*, between the bulbus cordis and the ventricle; the narrow passage which

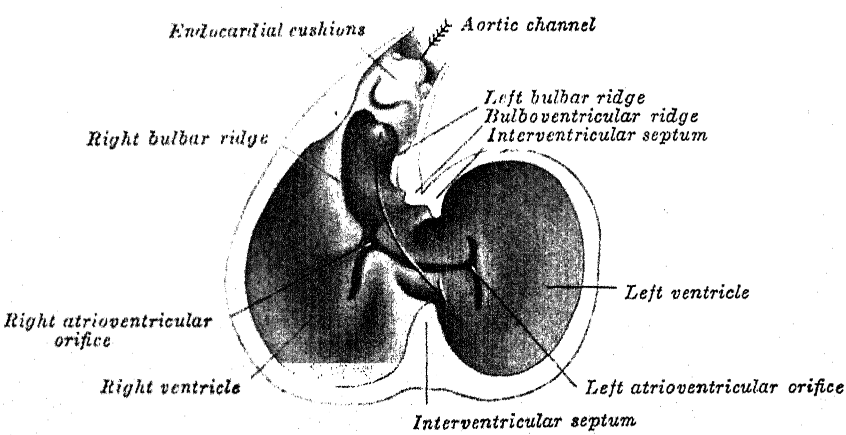
FIG. 178.—A diagram showing the relations at an early stage between the atrioventricular opening and ventricles, the cavity of the bulbus cordis, and the bulboventricular ridge. The endocardial cushions at the distal end of the bulb are shown in a more differentiated state than they really exhibit at this stage. (J. Ernest Frazer.)



connects these cavities is placed at the right of the atrioventricular orifice (fig. 178). The bulboventricular ridge soon disappears, and the opening from the ventricle into the bulbus cordis is widened, and lies over the right half of the atrioventricular opening (fig. 179). By the upgrowth of the ventricular septum the bulbus cordis is in great measure separated from the left ventricle, but remains an integral part of the right ventricle, of which it forms the infundibulum (fig. 177).

The truncus arteriosus and bulbus cordis are divided by a septum which makes its appearance in three portions. (1) Two ridge-like thickenings project into the lumen of the distal part of the truncus arteriosus; these increase in size and ultimately meet and fuse to form the *aortopulmonary septum* (fig. 176), which takes a

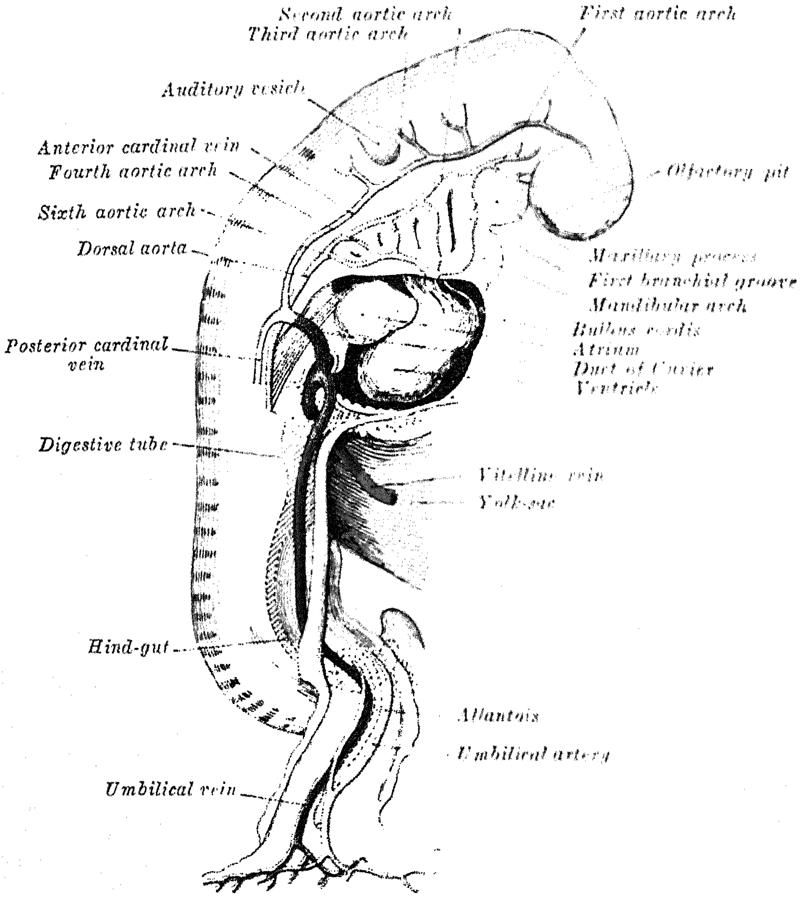
FIG. 179.—A diagram to show the intermediate stages of the aortic and pulmonary channels. (J. Ernest Frazer.)



spiral course towards the proximal end of the truncus arteriosus. It divides the truncus arteriosus into the aorta and the pulmonary artery. (2) Four endocardial cushions, anterior, posterior, right and left, appear at the distal end of the bulbus cordis (fig. 178). The right and left cushions meet and fuse to form the *distal bulbar*

septum which is joined by the aortopulmonary septum. (3) Two endocardial ridges, the *right and left bulbar ridges*, develop in the bulbus cordis (fig. 179) and unite to form the *proximal bulbar septum* which is continuous above with the distal bulbar septum. Its lower edge fuses with the ventricular septum and brings the right ventricle into communication with the pulmonary artery, and through the latter with the sixth pair of aortic arches; while the left ventricle is brought into continuity with the aorta, which communicates with the remaining aortic arches. The completed ventricular septum consists of a lower, muscular, and an upper, membranous, part; the former is developed from the septum inferius, the latter from the bulbar septum.

Fig. 180.—A human embryo estimated to be twenty or twenty-one days old. Right lateral aspect. (After His.)

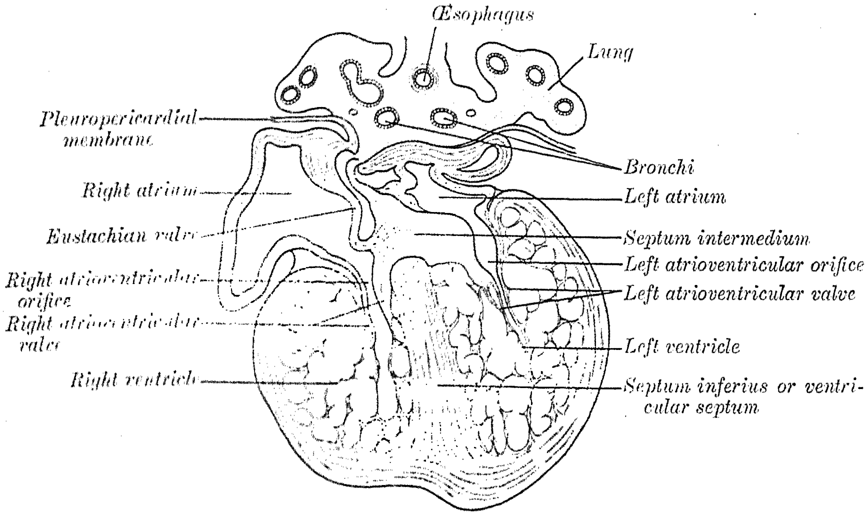


The valves of the heart.—The atrioventricular valves are developed in relation to the atrial canal. By the upward expansion of the bases of the ventricles the canal becomes invaginated into the ventricular cavities. The invaginated margin forms the rudiments of the lateral cusps of the atrioventricular valves; the medial or septal cusps of the valves are developed as downward prolongations of the septum intermedium (fig. 181). The aortic and pulmonary semilunar valves are formed from the four endocardial cushions which appear at the distal end of the bulbus cordis. When the aortopulmonary septum unites with the distal bulbar septum the lateral endocardial cushions are each divided into two, thus giving rise to six thickenings—the rudiments of the semilunar valves—three at the aortic and three at the pulmonary orifice.

Applied Anatomy.—In rare cases portions of the various cardiac septa may fail to develop, or some of the endocardial cushions may fuse in an abnormal manner giving rise

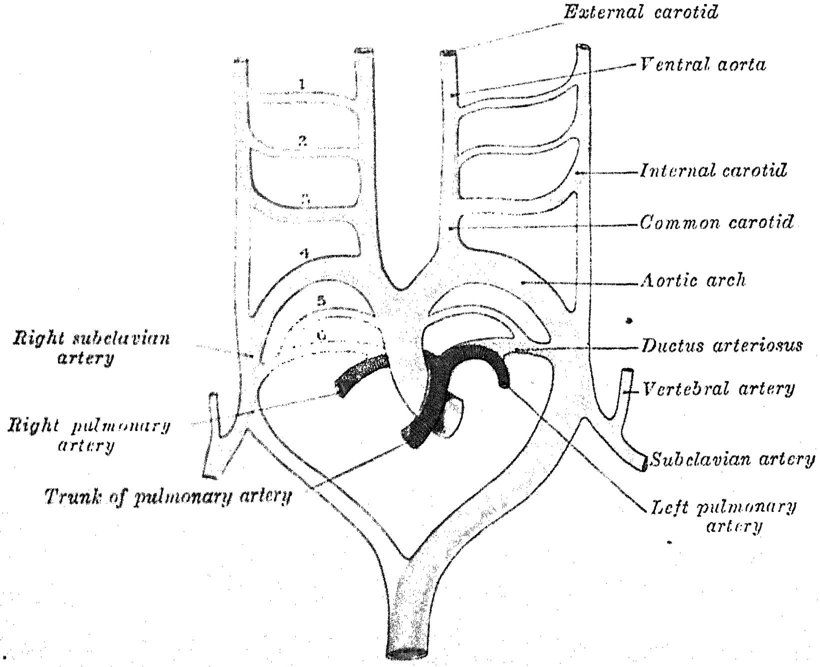
to various forms of congenital heart disease. Thus, the ventricular septum may fail almost entirely, and a heart with but one ventricle results; more commonly the failure is only partial, leaving a patent septum ventriculorum. Various degrees of patency of the foramen

FIG. 181.—Section of a fœtal heart. (His.)



ovale have also been noted. Stenosis (narrowing) of the aortic and pulmonary orifices may possibly be related to defective development of the bulbus cordis; sometimes there may be only two cusps in the aortic or pulmonary valves. Complete atresia (non-perforation) of the pulmonary orifice is a very rare anomaly.

FIG. 182.—A scheme of the aortic arches and their transformations. (Modified from Kollmann.)

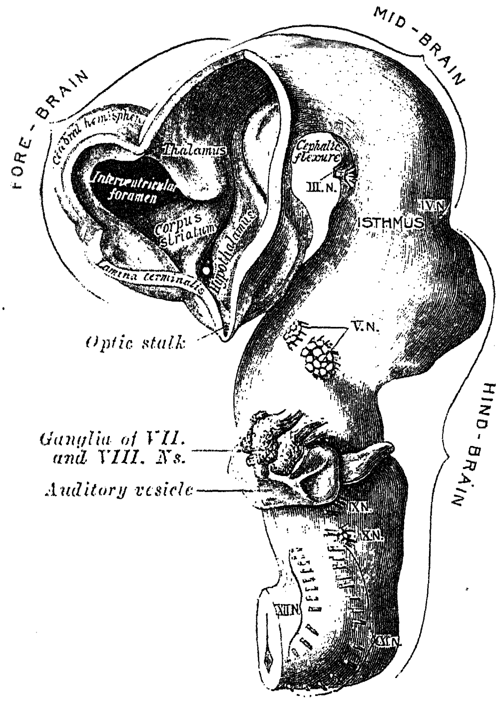


The further development of the arteries.—Recent observations show that none of the main vessels of the adult arise as single trunks in the embryo. At the site of

After the seventh month of fœtal life the cerebellum increases very rapidly in size.*

The **mesencephalon** or **mid-brain** (figs. 138 to 142) exists for a time as a thin-walled cavity of some size, and is separated by slight constrictions from the isthmus rhombencephali and the fore-brain. Its cavity becomes relatively reduced in diameter, and forms the cerebral aqueduct of the adult brain. The basal laminæ of the mid-brain increase in thickness to form the cerebral peduncles, which are at first of small size, but rapidly enlarge after the fourth month. Many of the neuroblasts of these laminæ are grouped in relation to the sides and floor of the cerebral aqueduct, and constitute the nuclei of the oculomotor and trochlear nerves, and of the mesencephalic root of the trigeminal nerve; others are aggregated to form the red nuclei. By a similar thickening process the alar laminæ are developed into the quadrigeminal lamina. The dorsal part of the wall expands, and for a time presents an internal median furrow and a corresponding external ridge; these, however, disappear, and the latter is replaced by a groove. Subsequently two oblique furrows extend medialwards and backwards, and the thickened lamina is thus subdivided into the superior and inferior colliculi.

Fig. 139.—The brain of a human embryo, about four and a half weeks old. (From a model by His.)



The **prosencephalon** or **fore-brain.**—A transverse section through the early fore-brain shows the same parts as are displayed in similar sections of the medulla spinalis and medulla oblongata, viz. a pair of thick lateral walls connected by thin floor- and roof-plates. Moreover, each lateral wall is divided into a dorsal or alar and a ventral or basal lamina separated internally by a furrow termed the *sulcus of Monro*. This sulcus ends anteriorly at the medial end of the optic stalk, and in the adult brain is retained as a slight groove extending backwards from the interventricular foramen to the cerebral aqueduct.

At a very early period—in some animals before the closure of the cranial part of the neural tube—two lateral diverticula, the *optic vesicles*, appear, one on either side of the fore-brain; for a time they communicate with the cavity of the fore-brain by relatively wide openings. The distal parts of the vesicles expand, while the proximal parts are reduced to tubular stalks, the *optic stalks*; their further development is given on pp. 101 to 104. The fore-brain then grows forwards, and from the alar laminæ of this front portion the cerebral hemispheres originate as diverticula which rapidly expand to form two large pouches, one on either side. The cavities of these diverticula are the rudiments of the lateral ventricles; they communicate with the median part of the fore-brain cavity by relatively wide openings which ultimately form the interventricular foramen (foramen of Monro). The median portion of the wall of the fore-brain vesicle consists of a thin lamina, the *lamina terminalis* (figs. 142, 145), which stretches from the interventricular foramen to the recess at the base of the optic stalk. The anterior part of the fore-brain, including the rudiments of the cerebral hemispheres, is named the *telencephalon*, and the posterior portion the *diencephalon*; both contribute to the formation of the third ventricle.

* Halbert L. Dunn, *Proceedings of the American Association of Anatomists, Anatomical Record,* vol. 21, No. 1, p. 55.

right common and external carotid arteries. The left gives rise to (*a*) the portion of the aortic arch between the origins of the innominate and left common carotid arteries ; (*b*) the left common and external carotid arteries.

The aortic arches.—The first and second arches disappear, but the dorsal end of the second gives origin to the stapedial artery (fig. 183), a vessel which atrophies in man but persists in some mammals (e.g. the rat).

The stapedial artery passes through the ring of the stapes and divides into supra-orbital, infra-orbital, and mandibular branches which follow the three divisions of the trigeminal nerve. The infra-orbital and mandibular branches arise from a common stem, the terminal part of which anastomoses with the external carotid. On the obliteration of the stapedial artery this anastomosis enlarges and forms the internal maxillary artery, and the branches of the stapedial artery are now branches of this vessel. The common stem of the infra-orbital and mandibular branches passes between the two roots of the auriculotemporal nerve and becomes the middle meningeal artery; the original supra-orbital branch of the stapedial artery is represented by the orbital twigs of the middle meningeal artery.

The third aortic arch constitutes the commencement of the internal carotid artery, and is therefore named the *carotid arch.* The fourth right arch forms the right subclavian as far as the origin of its internal mammary branch, while the fourth left arch constitutes the arch of the aorta between the origin of the left common carotid artery and the termination of the ductus arteriosus. The fifth arch disappears on both sides. The sixth right arch disappears ; the sixth left arch gives off the pulmonary arteries and forms the ductus arteriosus ; this duct remains pervious during fœtal life, but is obliterated a few days after birth and forms the ligamentum arteriosum of the adult. His showed that in the early embryo the sixth arch on either side gives a branch to the corresponding lung, but later both pulmonary arteries take origin from the left arch.

The dorsal aorta.—In front of the third aortic arches the dorsal aortæ persist and form the continuations of the internal carotid arteries ; these arteries pass to the brain, and each divides into an anterior and a posterior branch, the former giving off the ophthalmic artery and the anterior and middle cerebral arteries, while the latter turns back and joins the cerebral part of the vertebral artery. Behind the third arch the right dorsal aorta disappears as far as the point where the two dorsal aortæ fuse to form the descending aorta. The part of the left dorsal aorta between the third and fourth arches disappears, while the remainder persists to form the descending part of the arch of the aorta. A constriction, the *aortic isthmus,* is sometimes seen in the aorta between the origin of the left subclavian artery and the attachment of the ductus arteriosus.

Sometimes the right subclavian artery arises from the aortic arch distal to the origin of the left subclavian and passes upwards and to the right behind the trachea and œsophagus. This condition may be explained by the persistence of the right dorsal aorta and the obliteration of the fourth right arch.

In birds the fourth right arch forms the arch of the aorta ; in reptiles the fourth arch persists on both sides and gives rise to the double aortic arch in these animals.

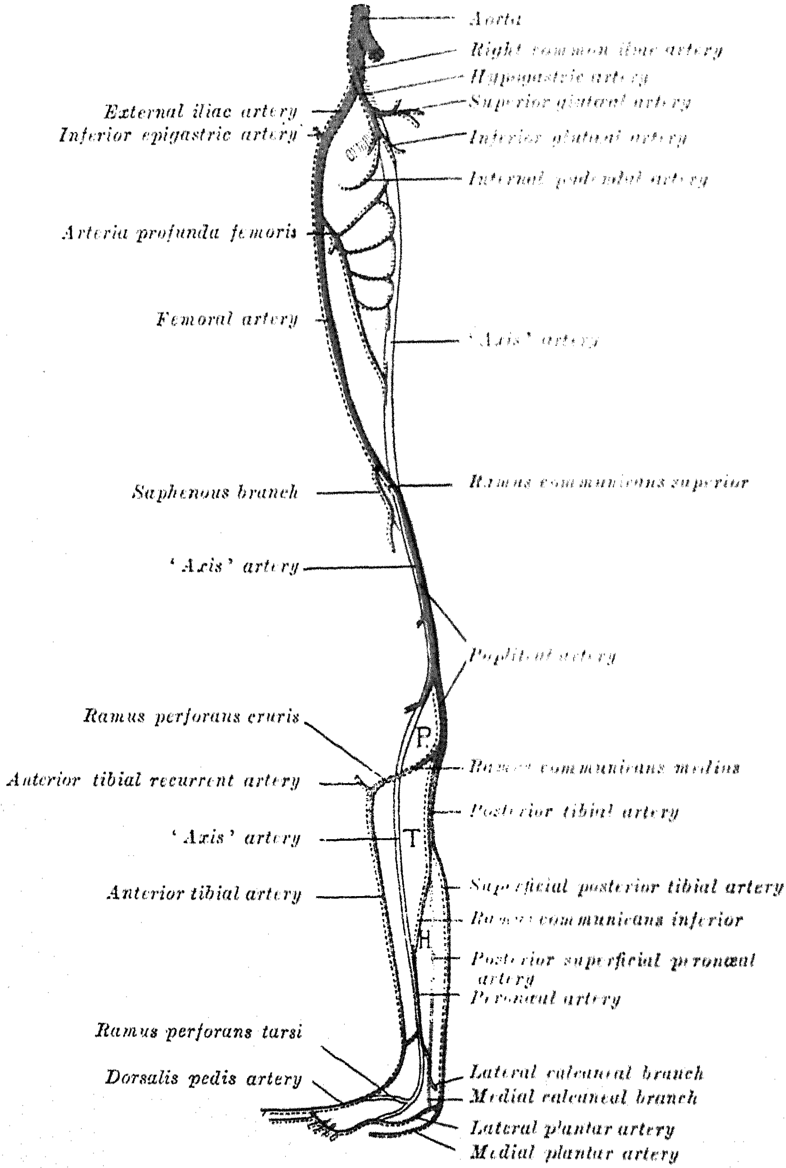
The heart originally lies on the ventral aspect of the pharynx, immediately caudal to the stomodæum (fig. 180) ; with the elongation of the neck and the development of the lungs it recedes within the thorax, and, as a consequence, the anterior ventral aortæ are drawn out and the original position of the fourth and fifth arches is greatly modified. Thus, on the right side the fourth arch recedes to the root of the neck, while on the left side it is withdrawn within the thorax. The recurrent nerves originally pass to the larynx under the sixth pair of arches, and are therefore pulled backwards with the descent of these structures, so that in the adult the left nerve hooks round the ligamentum arteriosum ; owing to the disappearance of the fifth and the sixth right arches the right nerve hooks round that immediately above them, i.e. the commencement of the subclavian artery.

The primitive dorsal aortæ give off ventral, dorsal, and lateral groups of segmental arteries.

The *ventral* segmental arteries, the first to be developed, are originally paired vessels, but, after the fusion of the dorsal aortæ, appear as unpaired trunks ; they are distributed to the primitive digestive tube and to the wall of the yolk-sac. Three of them persist and constitute the cœliac, superior mesenteric, and inferior

mesenteric arteries of the adult. As the viscera supplied by these three arteries descend into the abdomen, the vessels at the same time wander in a caudal direction; thus, the origin of the cœliac artery is transferred from the level of the seventh cervical to that of the twelfth thoracic segment, the superior mesenteric from

Fig. 184.—A diagram to illustrate the general development of the arteries of the lower limb. The letter P indicates the position of the Popliteus: T that of the Tibialis posterior; and H that of the Flexor hallucis longus. (H. D. Senior.)



the second thoracic to the first lumbar segment, and the inferior mesenteric from the twelfth thoracic to the third lumbar segment.

The *dorsal* segmental arteries are at first distributed to the neural tube, but later give off parietal branches to the body-wall; these parietal branches persist in the thoracic and lumbar regions as the intercostal and lumbar arteries. From the seventh pair the entire left subclavian artery, the greater part of the right subclavian artery, and the proximal part of the vertebral artery are derived; the main part

of the cervical portion of the vertebral artery is developed from a longitudinal anastomosis between the first seven dorsal segmental arteries. The second dorsal segmental arteries run alongside the hypoglossal nerves to the brain and are named the hypoglossal arteries. Each sends forwards a branch which forms the cerebral part of the vertebral artery and anastomoses with the posterior branch of the internal carotid artery; the cerebral portions of the two vertebrals unite on the ventral surface of the pons to form the basilar artery. The hypoglossal arteries atrophy, and then the cervical and cerebral parts of the vertebrals are connected by means of the first pair of segmental arteries.

The *lateral* segmental arteries supply, on either side, the mesonephros or Wolffian body and give branches to the testis (or ovary) and the suprarenal glands. One testicular (or ovarian) artery and three suprarenal arteries persist on either side. The inferior phrenic artery arises as a branch from the first, and the renal artery as a branch from the third suprarenal artery. Additional renal arteries are frequently present and may be looked on as branches of persistent lateral segmental arteries.

The arteries of the limbs.—Several small arteries pass from the dorsal aorta into the upper limb-bud, and form in it a free capillary anastomosis. Only one of these arteries persists to form the arterial stem (subclavian artery) and the origin of this persistent vessel is transferred from the dorsal aorta to the seventh segmental artery. The subclavian artery is prolonged into the limb under the names of the axillary and brachial arteries, and these together constitute the arterial stem for the upper arm; the continuation of this stem in the forearm is represented by the volar interosseous artery. A branch which accompanies the median nerve soon increases in size and forms the main vessel (median artery) of the forearm, while the volar interosseous diminishes. Later the radial and ulnar arteries are developed as branches of the brachial part of the stem and coincidently with their enlargement the median artery dwindles: occasionally it persists as a vessel of some size and accompanies the median nerve into the palm of the hand.

Senior has recently worked out the development of the arteries of the lower limb, and the following description is based on his observations.*

The primary arterial trunk (fig. 184) or 'axis' artery of the lower limb arises from the dorsal root of the umbilical artery, and courses along the dorsal surface of the thigh, knee and leg: below the knee it lies between the tibia and the Popliteus muscle, and in the leg between the crural interosseous membrane and the Tibialis posterior muscle. It ends distally in a rete plantare, and gives off a perforating artery (ramus perforans tarsi) which traverses the sinus tarsi and forms a rete dorsale. The femoral artery passes along the ventral surface of the thigh, and opens up a new channel to the lower limb. It arises from a plexus of capillaries which is connected proximally with the femoral branches of the external iliac artery, and distally with the ramus communicans superior of the axis artery. At the proximal margin of the Popliteus the axis artery gives off two vessels, viz.: the posterior superficial tibial, and the posterior superficial peroneal arteries, and at the distal margin of the same muscle it supplies a perforating branch (ramus perforans cruris) to the front of the leg. A middle and an inferior communicating artery pass from the superficial peroneal to the axis artery, the former at the distal border of the Popliteus, and the latter at the distal border of the Tibialis posterior.

The femoral artery gradually increases in size, and coincidently with this increase almost the whole of the axis artery, proximal to the ramus communicans superior disappears; the root of the axis artery, however, persists as the inferior glutæal artery. Two other segments of the distal part of the axis artery are maintained; one, just beyond the ramus communicans superior, which forms the proximal part of the popliteal artery, the other, near the ankle, which forms a part of the peroneal artery.

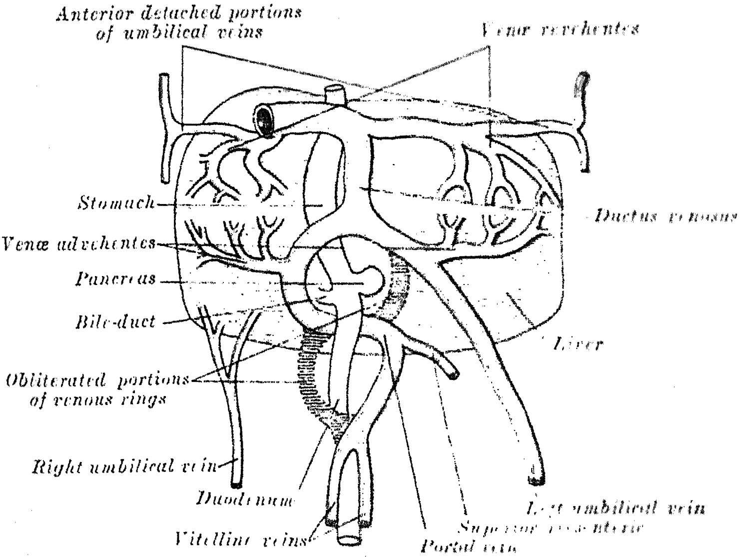
The proximal portions of the posterior superficial tibial and posterior superficial peroneal arteries fuse and form (*a*) the distal part of the popliteal artery, and (*b*) the first part of the posterior tibial artery, i.e. as far as the point where it gives off the peroneal artery. The posterior superficial tibial artery ends in the medial plantar artery, and is largely retained to form the greater part of the posterior tibial artery. The posterior superficial peroneal artery ends in the lateral plantar artery, but the latter vessel is subsequently transferred to the posterior tibial artery. The

* H. D. Senior, *American Journal of Anatomy*, vol. xxv. 1919, and *Anatomical Record*, vol. xvii. 1920.

part of the posterior superficial peroneal artery just distal to its fusion with the posterior superficial tibial forms the proximal part of the peroneal artery, the remainder of the latter vessel consisting of (*a*) the ramus communicans inferior, (*b*) a short persistent part of the axis artery, and (*c*) the distal portion of the posterior superficial peroneal artery and its lateral calcaneal branch. The anterior tibial artery is derived from (*a*) the ramus communicans medius, (*b*) a short section of the axis artery, (*c*) the ramus perforans cruris and its continuation to the ankle (arteria tibialis anterior pars distalis). The arteries which are distributed on the dorsum of the foot are derived from the rete dorsale, while the plantar arch and its digital branches originate from the rete plantare.

The **further development of the veins.**—The principal veins of the embryo may be divided into two groups, visceral and parietal.

FIG. 185.—The liver, and the veins in connexion therewith, of a human embryo, twenty-four or twenty-five days old. Ventral aspect. (After His.)



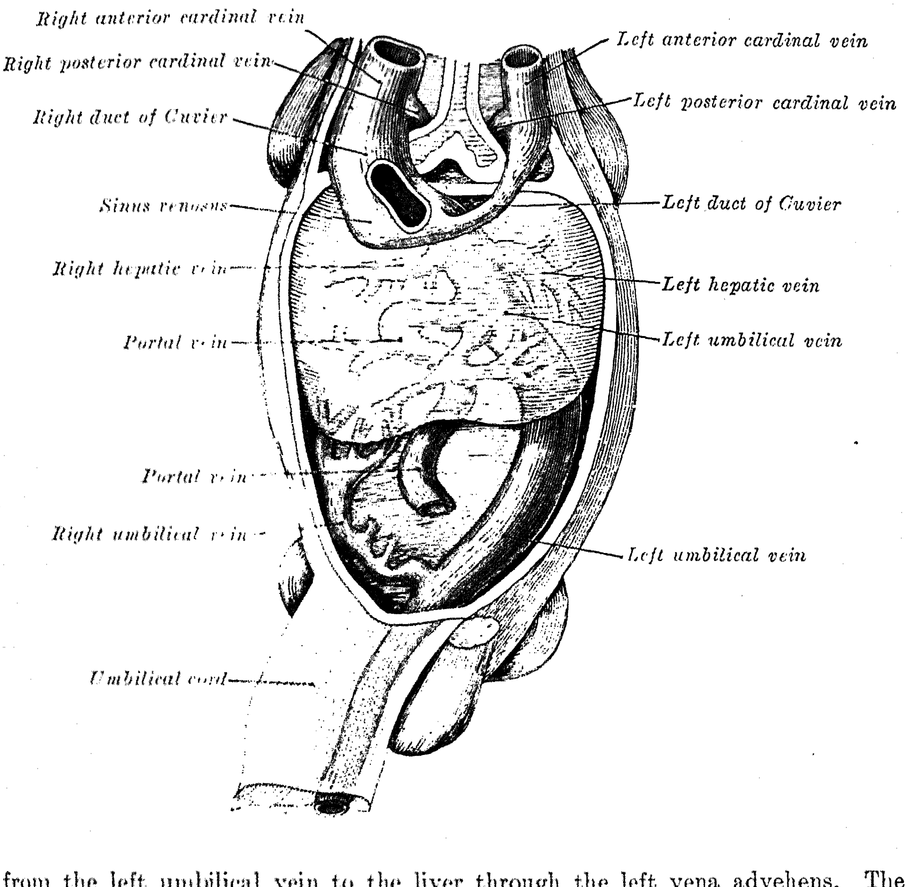
The visceral veins are the two vitelline veins bringing the blood from the yolk sac, and the two umbilical veins returning the blood from the placenta; these four veins open close together into the sinus venosus.

The vitelline veins run upwards at first in front, and subsequently on either side, of the digestive tube. They unite on the ventral surface of the tube, and beyond this are connected to one another by two anastomotic branches, one on the dorsal and the other on the ventral aspect of the duodenal portion of the intestine, which is thus encircled by two venous rings forming the figure 8 (fig. 185); into the middle or dorsal anastomosis the superior mesenteric vein opens. The portions of the veins above the upper ring become connected with a plexus of small capillary-like vessels termed *sinusoids* which form in the developing liver. The vessels conveying the blood to this plexus are named the *venæ advehentes*, and become the branches of the portal vein; while the vessels draining the plexus into the sinus venosus are termed the *venæ revehentes*, and form the future hepatic veins (figs. 185, 186). After a time the left vena revehens no longer communicates directly with the sinus venosus, but opens into the upper part of the right vena revehens (right hepatic vein). The persistent part of the upper venous ring, above the opening of the superior mesenteric vein, forms the trunk of the portal vein.

The two umbilical veins fuse to form a single trunk, the *vena umbilicalis impar*, in the umbilical cord; this trunk divides within the embryo into the right and left umbilical veins which pass forwards to the sinus venosus in the side walls of the body. Like the vitelline veins, the direct connexion of the umbilical veins with the sinus venosus becomes interrupted by the developing liver, and the whole of the

blood from the yolk-sac and placenta passes through the substance of the liver before it reaches the heart. The right umbilical and right vitelline veins shrivel and disappear; the left umbilical, on the other hand, enlarges and opens into the upper venous ring of the vitelline veins; with the atrophy of the yolk-sac the left vitelline vein shrivels and disappears. Finally, a direct branch named the *ductus venosus* is established between the upper venous ring and the right hepatic vein; the ductus venosus enlarges rapidly and forms a wide channel through which most of the blood, returned from the placenta, is carried direct to the heart without passing through the liver. A small part of the blood from the placenta is, however, conveyed

FIG. 186.—A human embryo with the heart and anterior body wall removed to show the sinus venosus and its tributaries. (After His.)



from the left umbilical vein to the liver through the left vena advehens. The left umbilical vein and the ductus venosus are obliterated after birth, and form respectively the ligamentum teres and ligamentum venosum of the liver.

The parietal veins.—A pair of short transverse veins, named the *ducts of Cuvier*, open, one on either side, into the sinus venosus. Each of these ducts receives an ascending and a descending vein. The ascending veins return the blood from the parietes of the trunk and from the Wolffian bodies, and are called *posterior cardinal* veins. The descending veins return the blood from the head, and are called the *anterior cardinal* (primitive jugular) veins (fig. 187). The blood from the lower limbs is collected by the right and left iliac and hypogastric veins, which, in the earlier stages of development, open into the corresponding right and left posterior cardinal veins; later, a transverse branch (the left common iliac vein) is developed between the lower parts of the posterior cardinal veins (fig. 189), and through this the blood is carried into the right posterior cardinal vein. The portion of the left posterior cardinal vein below the left renal vein atrophies and disappears up to the point of entrance of the left testicular vein; the portion above the left renal vein persists

as the hemiazygos and accessory hemiazygos veins and the lower portion of the left superior intercostal vein. The right posterior cardinal vein, which now receives the blood from both lower extremities, forms a large venous trunk along the posterior abdominal wall; up to the level of the renal veins it forms the lower part of the inferior vena cava. Above the level of the renal veins the right posterior cardinal vein persists as the azygos vein and receives the right intercostal veins, while the hemiazygos and accessory hemiazygos veins are brought into communication with it by the development of transverse branches in front of the vertebral column (figs. 189, 190).

The inferior vena cava.—The development of the inferior vena cava is associated with the formation of two veins, the *subcardinal veins* (figs. 187, 188). These run along the medial surfaces of the Wolffian bodies parallel to the posterior cardinal veins; they communicate with the posterior cardinal veins above and below, and

FIG. 187.—A scheme of the arrangement of the parietal veins.

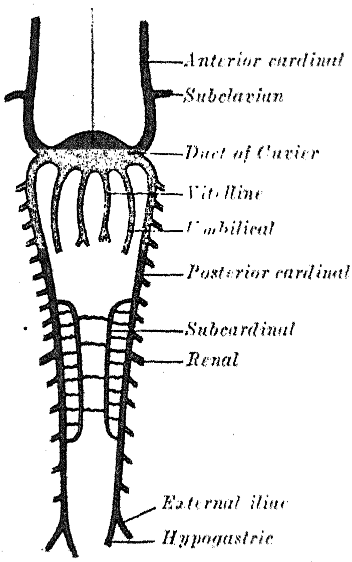
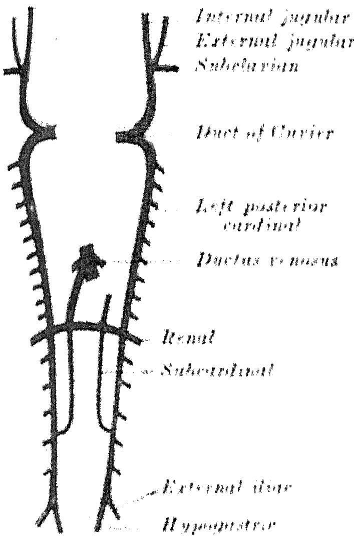


FIG. 188.—A scheme showing the early stages of the development of the inferior vena cava.

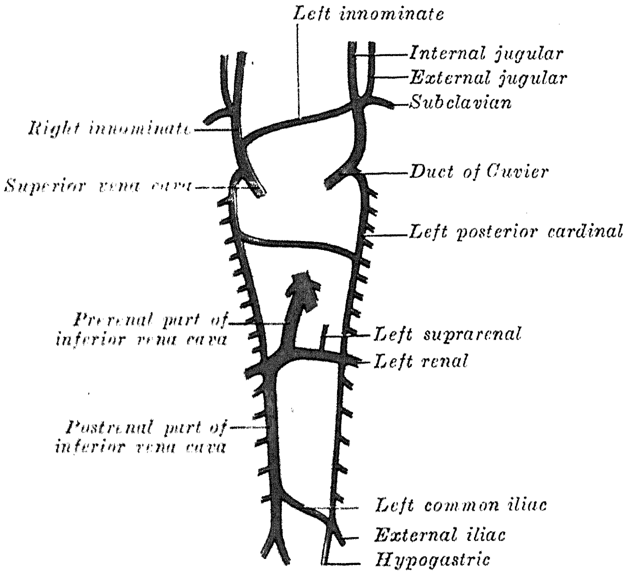


also by a series of transverse branches. The two subcardinals are for a time connected with each other in front of the aorta by cross branches, but these disappear and are replaced by a single transverse channel (intersubcardinal anastomosis) at the level where the renal veins join the posterior cardinals, and at the same level a cross communication is established on either side between the posterior cardinal and subcardinal (fig. 188). The portion of the right subcardinal behind this cross communication disappears, while that in front (i.e. the prerenal part) becomes connected by means of a channel with the proximal part of the right hepatic vein, and this channel rapidly enlarges and receives the blood from the postrenal part of the right posterior cardinal through the cross communication referred to. In this manner a single trunk, the *inferior vena cava* (fig. 190), is formed, and consists of the proximal part of the right hepatic vein, the new channel just described, the prerenal part of the right subcardinal vein, the postrenal part of the right posterior cardinal vein, and the cross branch connecting it with the right subcardinal vein. The left subcardinal disappears, except the part immediately in front of the renal vein, which is retained as the left suprarenal vein. The testicular (or ovarian) vein opens into the postrenal part of the corresponding posterior cardinal vein. This portion of the right posterior cardinal, as already explained, forms the lower part of the inferior vena cava, so that the right testicular opens directly into that vessel. The postrenal segment of the left posterior cardinal disappears, with the exception of the portion between the testicular and renal veins, which is retained as the terminal part of the left testicular vein.

Huntington and McClure * contend (1) that the right posterior cardinal vein takes no share in the development of the postrenal segment of the inferior vena cava, and (2) that it forms only the cranial end of the azygos vein.

They state that a *supracardinal system of veins*, consisting of a bilateral and originally symmetrical venous channel, is developed dorsomedial to the posterior cardinal veins and dorsolateral to the aorta. Frequent anastomoses occur between the posterior cardinal and supracardinal veins, but only a single anastomosis, at about the level of the inter-subcardinal anastomosis, is retained on each side of the body; this anastomosis permits blood, collected by the supracardinal veins in the lumbar region, to reach the heart by way of the prerenal division of the inferior vena cava. The formation of this anastomosis establishes the presence of a circumaortic venous ring, named the *renal collar*. The supracardinal veins unite (*a*) caudally with the posterior cardinal veins at the level where

FIG. 189.—A diagram showing the development of the main cross branches between the cardinal veins.



the latter receive the internal iliac and hypogastric veins, and (*b*) cranially at the level of the renal collar, and thus there is established for a time a venous ring through which the ureter passes.

The supracardinal veins soon separate into a cranial or azygos, and a caudal or lumbar, pair of veins, and the bilaterally symmetrical plan of the latter is replaced by an asymmetrical one which is initiated by a reduction, followed by a complete atrophy, of the left half of the renal collar; the right half of this collar persists and elongates to form a part of the postrenal segment of the inferior vena cava. The caudal half of the left supracardinal vein is drawn into and fuses with the vein of the right side, and from these fused veins the caudal part of the postrenal segment of the inferior vena cava is formed.

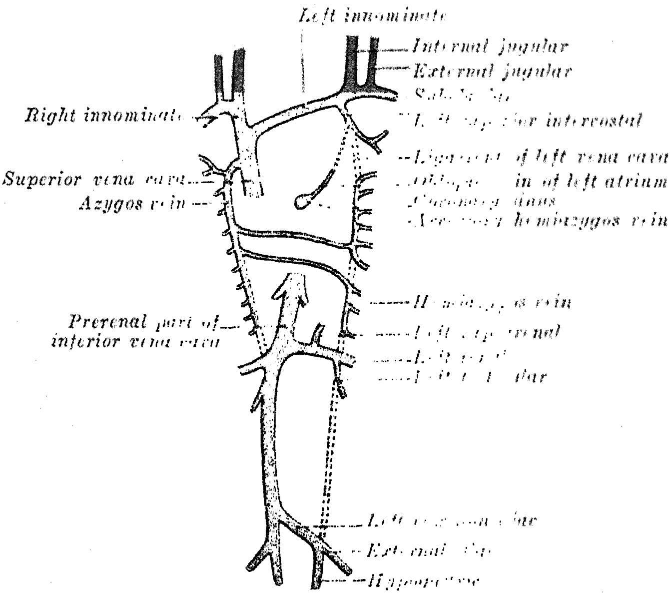
The history of the development of the azygos veins in the cat shows "that they are derived chiefly from the supracardinals, and that in the adult cat only the proximal end of the right azygos near the duct of Cuvier is derived from the posterior cardinal vein."

In consequence of the atrophy of the Wolffian bodies the posterior cardinal veins diminish in size; the anterior cardinal veins, on the other hand, become enlarged, owing to the rapid development of the head and brain. They are further augmented by receiving the veins (*subclavian*) from the upper extremities, and so come to form the chief veins of the ducts of Cuvier; these ducts gradually assume an almost vertical position in consequence of the descent of the heart into the thorax. The right and left ducts of Cuvier are originally of the same diameter, and are frequently termed the *right and left superior venæ cavæ*. By the development of a transverse branch (the *left innominate vein*) between the two anterior cardinal veins, the blood

* G. S. Huntington and C. F. W. McClure, *Anatomical Record*, vol. xx, December 1920.

is carried across from the left to the right anterior cardinal (figs. 189, 190). The portion of the right anterior cardinal vein between the left innominate and the azygos vein forms the upper part of the superior vena cava of the adult; the lower part of the latter vessel (i.e. below the entrance of the azygos vein) is formed by the right duct of Cuvier. Below the origin of the transverse branch the left anterior cardinal vein and left duct of Cuvier atrophy, the former constituting the upper part of the left superior intercostal vein, while the latter is represented by the ligament of the left vena cava (vestigial fold of Marshall) and the oblique vein of the left atrium (oblique vein of Marshall) (fig. 190). The oblique vein of the left atrium passes downwards across the back of the left atrium to open into the coronary sinus, which, as already indicated, represents the persistent left horn of the sinus venosus. Right and left superior venæ cavæ are present in some animals, and are occasionally found in the adult human being.

FIG. 190.—A diagram showing the completion of the development of the parietal veins.



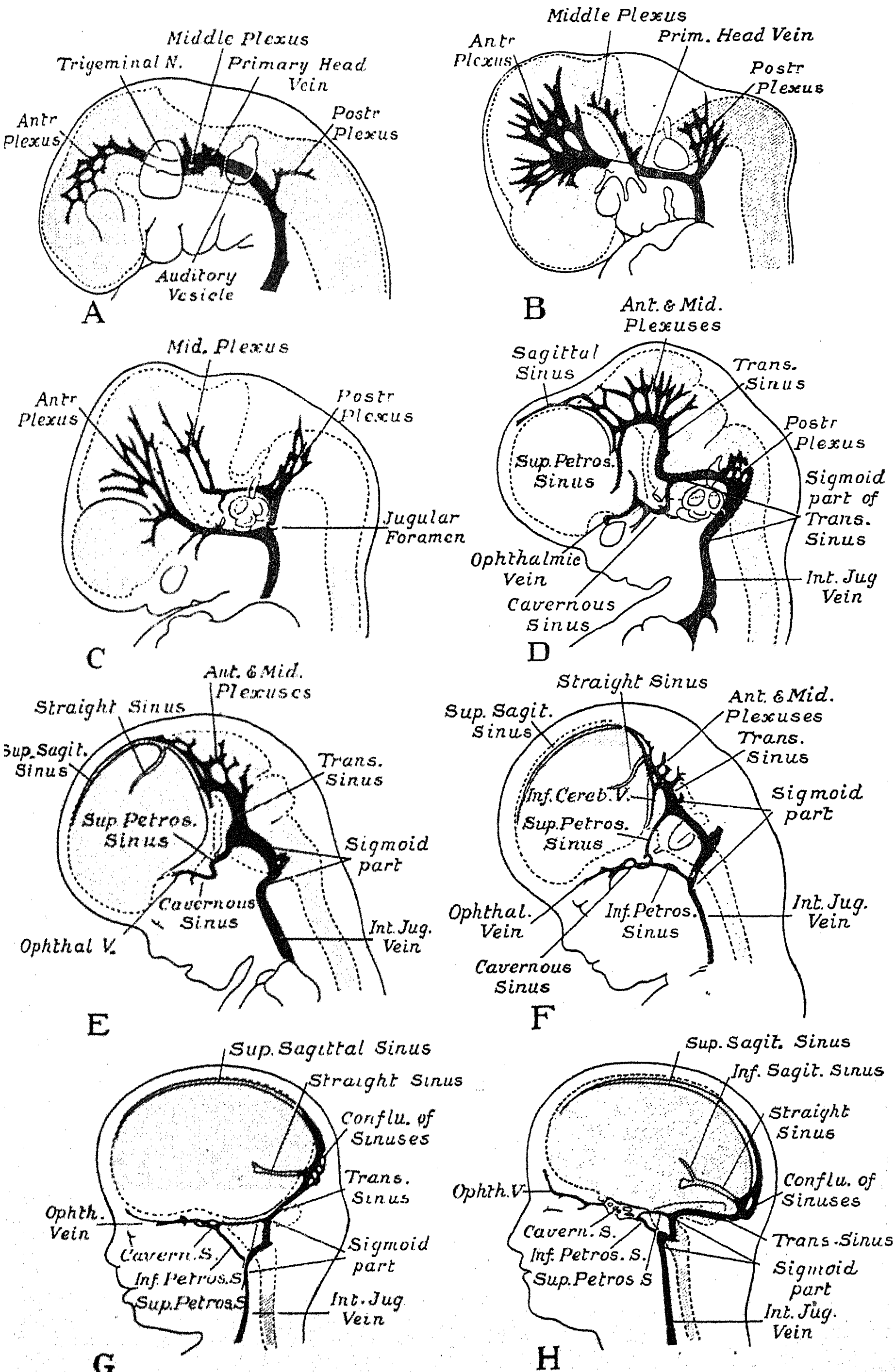
The venous sinuses of the dura mater. The following description is based on that given by Streeter.*

The primary blood-vessels of the head consist of a close-meshed capillary plexus which is drained by anastomosing loops into a pair of veins, named the *primary head veins.* Each primary head vein (fig. 191 *A*) begins on the diencephalon, and courses along the side of the brain running medial to the semilunar ganglion and lateral to the auditory vesicle; on reaching the vagus nerve it turns sharply downwards and opens into the duct of Cuvier. The part of the vein which is caudal to the vagus nerve is the anterior cardinal vein, the cephalic portion of which forms the internal jugular vein. At a later stage the greater part of the original capillary plexus assumes the form of three secondary plexuses—anterior, middle and posterior (fig. 191, *B*, *C*); the middle and posterior plexuses each open by a single vein into the primary head vein. Some tributaries from the ventral part of the head also enter this vein; the most important of these are the channels from the eye-region, and these later become the ophthalmic veins.

The development of the cranium and the brain membranes introduces further changes: the three main secondary plexuses are largely retained in association with the dura mater, while superficial portions are split off to drain the surface of the head, and deeper portions are specialized for the drainage of the brain-stem. The next

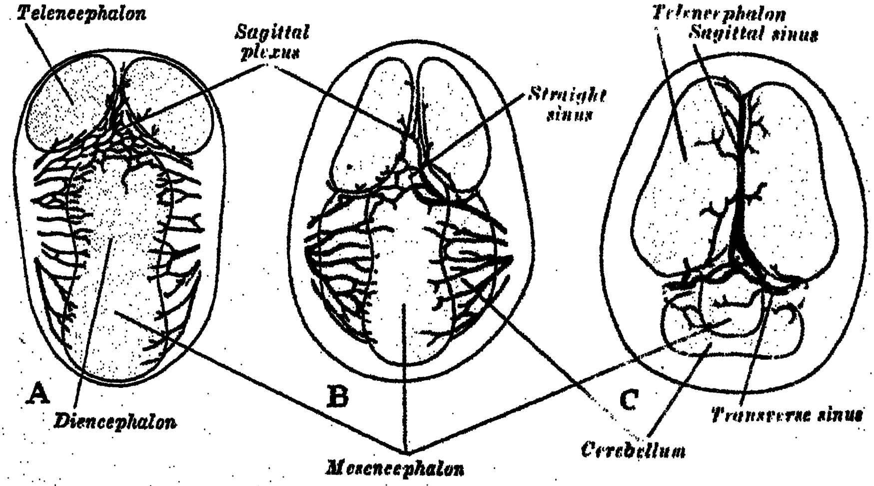
* George L. Streeter, *American Journal of Anatomy*, vol. xviii. 1915.

FIG. 191.—Profile drawings showing the development of the venous sinuses of the dura mater in human embryos from 4 mm. to birth. Their adaptation to the growth and changes in the form of the brain should be noted. A. Embryo of 4 mm.; B. Embryo of 14 mm.; C. Embryo of 18 mm.; D. Embryo of 21 mm.; E. Embryo of 35 mm.; F. Embryo of 50 mm. crown-rump length; G. Embryo of 80 mm. crown-rump length; H. At birth. (George L. Streeter.)



series of modifications is largely due to the increase in the size of the internal ear. An anastomosing channel between the middle and posterior plexuses forms on the dorsal aspect of the auditory vesicle, and the anterior and middle plexuses unite with one another (fig. 191, *C, D*). A single large vein which is the commencement of the transverse sinus drains the anterior and middle plexuses into the new anastomosing channel (fig. 191, *D*). The posterior part of the primary head vein, i.e. the part connected with the internal jugular vein, disappears, but the anterior portion, in the region of the trigeminal nerve, is retained as the cavernous sinus, and into this the ophthalmic veins open (fig. 191, *D, E*). The original stem of the middle plexus, between the new anastomosing channel and the primary head vein, undergoes atrophy, but later is re-established as the superior petrosal sinus (fig. 191, *E, F, G*). The inferior petrosal sinus is a new formation, developed from a small plexus between the cavernous sinus and the internal jugular vein (fig. 191, *F, G*).

FIG. 192.—Three stages in the formation of the sagittal plexus, showing its conversion into the superior sagittal sinus. Draining into it from below is the channel from the chorioidal plexuses which becomes the straight sinus (fig. B.). A. From a human embryo 13·8 mm. long; B. From a human embryo 20 mm. long; C. is a drawing of an injected and cleared specimen 54 mm. long. (George L. Streeter.)



The transverse sinus at this stage can be recognized as a composite vessel derived from (1) the stem of the conjoined anterior and middle plexuses, (2) the anastomosing channel dorsal to the auditory vesicle, and (3) the stem of the posterior plexus continued into the internal jugular vein; the second and third portions together form the sigmoid part of the sinus.

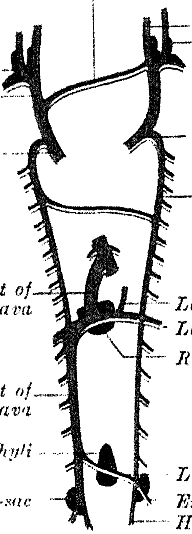
Between the growing cerebral hemispheres extensions of the anterior and middle plexuses of both sides meet and form the *sagittal plexus* (fig. 192, *A, B*), a curtain of capillary veins which hangs down in the position of the future falx cerebri. Along the dorsal margin of this curtain the superior sagittal sinus is evolved, and this sinus usually joins the right transverse sinus (fig. 192, *B, C*); along the ventral free edge of the curtain the inferior sagittal sinus and the straight sinus are formed, the latter passing into the left transverse sinus. When the cerebral hemispheres grow backwards they carry with them the sagittal sinus; the straight sinus extends backwards through a plexus in the tentorium cerebelli, and the transference of both sinuses is continued until they arrive at their adult positions with their point of junction at the confluence of the sinuses (torcular Herophili). The posterior plexus establishes a secondary connexion with the confluence of the sinuses; loses its connexion with the sigmoid part of the transverse sinus, and is retained as the occipital sinus.

The external jugular vein at first drains the region behind the ear (posterior auricular) and enters the anterior cardinal as a lateral tributary. A group of veins

from the face and lingual region converge to form a common vein, the linguofacial,* which also terminates in the anterior cardinal vein. Later, cross communications develop between the external jugular and the linguofacial, with the result that the posterior group of facial veins is transferred to the external jugular. The cephalic vein is, for a time, a tributary of the external jugular vein, but is later diverted into the axillary vein.

In early fœtal life the heart is placed directly under the head and is relatively of large size. Later it assumes its position in the thorax, but lies at first in the middle line ; towards the end of pregnancy it gradually becomes oblique in direction. The atrial portion is at first larger than the ventricular part, and the two atria communicate freely through the foramen ovale. In consequence of the communication, through the ductus arteriosus, between the pulmonary artery and the aorta, the contents of the right ventricle are mainly carried into the latter vessel instead

Fig. 193.—A scheme showing the relative positions of the primary lymph-sacs. (Based on the description given by Florence Sabin.)



of to the lungs, and hence the wall of the right ventricle is as thick as that of the left. At the end of fœtal life, however, the left ventricle is thicker than the right, a difference which becomes more and more emphasised after birth.

The fœtal circulation and the changes which take place in the circulation after birth are described in the section on Angiology.

The **lymphatic vessels.**—The lymphatic system begins as a series of sacs † at the points of junction of certain of the embryonic veins. These lymph-sacs are developed by the confluence of numerous venous capillaries, which at first lose their connexions with the venous system, but subsequently, on the formation of the sacs, regain them. The lymphatic system is therefore developmentally an offshoot of the venous system, and the lining walls of its vessels are always endothelial.

In the human embryo the lymph-sacs from which the lymphatic vessels are derived are six in number ; two paired, the jugular and the posterior lymph-sacs ; the two unpaired, the retroperitoneal and the cisterna chyli. In lower mammals an additional pair, the subclavian, is present, but in the human embryo these are merely extensions of the jugular sacs.

The position of the sacs is as follows (fig. 193) : (1) the jugular, the first to appear, at the junction of the subclavian vein with the anterior cardinal ; (2) the posterior,

* Lewis, *American Journal of Anatomy*, vol. ix. 1909.

† F. Sabin, *American Journal of Anatomy*, vol. ix. 1909.

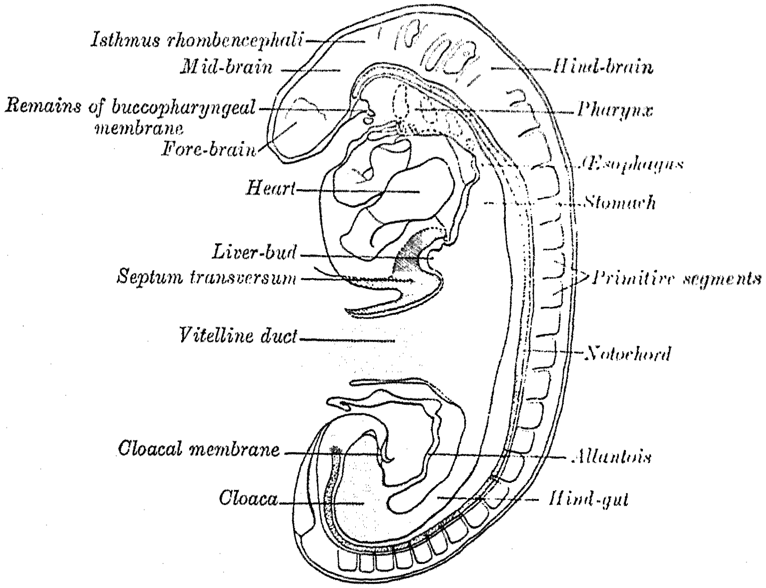
at the junction of the iliac vein with the posterior cardinal; (3) the retroperitoneal, in the root of the mesentery near the suprarenal glands; (4) the cisterna chyli, opposite the third and fourth lumbar vertebræ. From the lymph-sacs the lymphatic vessels bud out along fixed lines corresponding more or less closely with the course of the embryonic blood-vessels. In the body-wall and in the wall of the intestine,* the deeper plexuses are the first to be developed; by continued growth of these, the vessels in the superficial layers are gradually formed. The thoracic duct is probably formed from anastomosing outgrowths from the jugular sac and cisterna chyli. At its connexion with the cisterna chyli it is at first double, but the vessels soon join.

All the lymph-sacs except the cisterna chyli are, at a later stage, divided up by slender connective tissue bridges and transformed into groups of lymph-glands. The lower portion of the cisterna chyli is similarly converted, but its upper portion remains as the adult cisterna.

THE DEVELOPMENT OF THE DIGESTIVE AND RESPIRATORY APPARATUS

The **digestive tube**.—As already indicated (p. 55), the primitive digestive tube consists of two parts, viz.: (1) the *fore-gut*, within the cephalic flexure, and dorsal to the heart; and (2) the *hind-gut*, within the caudal flexure (fig. 194). Between

Fig. 194.—The digestive tube of a human embryo 2·5 mm. long. (Peter Thompson.)



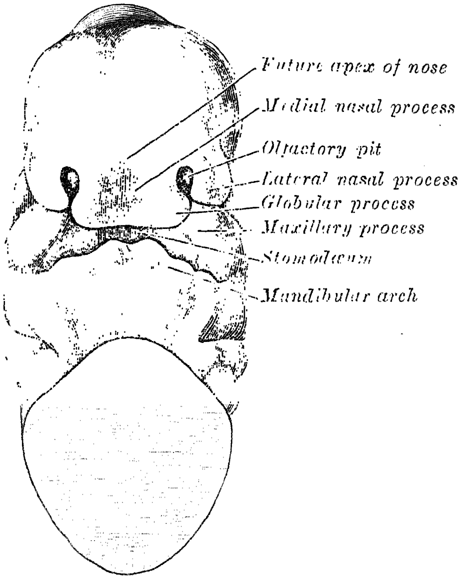
these is the wide opening of the yolk-sac, which is gradually narrowed and reduced to a small foramen leading into the vitelline duct. At first the fore-gut and hind-gut end blindly; the anterior end of the fore-gut is closed by the buccopharyngeal membrane; the hind-gut ends in the cloaca, which is similarly closed by the cloacal membrane.

The **mouth** is developed partly from the stomodæum, and partly from the floor of the anterior portion of the fore-gut. By the growth of the head-end of the

* Heuer, *American Journal of Anatomy*, vol. ix. 1909

embryo, and the formation of the cephalic flexure, the pericardial area and the buccopharyngeal membrane come to lie on the ventral surface of the embryo. With the further expansion of the brain, and the forward bulging of the pericardium, the buccopharyngeal membrane is depressed between these two prominences. This depression constitutes the *stomodæum* (fig. 195). It is lined with ectoderm, and is separated from the anterior end of the fore-gut by the buccopharyngeal membrane, which is formed by the apposition of the stomodæal ectoderm with the fore-gut entoderm; at the end of the third week the membrane disappears, and a communication is established between the mouth and the future pharynx. No trace of the membrane is found in the adult; and the communication just mentioned must not be confused with the permanent isthmus faucium. The lips, teeth, and gums are formed from the walls of the stomodæum, but the tongue is developed in the floor of the mouth and pharynx.

Fig. 195.—The head-end of a human embryo about thirty to thirty-one days old. Ventral aspect. (From a model by K. Peter.)



The visceral arches grow in a ventral direction and lie between the stomodæum and the pericardium; with the completion of the mandibular arch and the formation of the maxillary processes, the mouth assumes the appearance of a pentagonal orifice, bounded in front by the frontonasal process, behind by the mandibular arch, and laterally by the maxillary processes (fig. 195). With the inward growth and fusion of the palatine processes (figs. 124, 125), the stomodæum is divided into an upper nasal and a lower buccal part. Along the free margins of the processes bounding the mouth cavity a shallow groove appears; this is termed the *primary labial groove*, and from the bottom of it a downgrowth of ectoderm into the underlying mesoderm takes place. Owing to the degeneration of the central cells of this ectodermal downgrowth the groove is deepened and a *secondary labial groove* is formed, and separates the lips and cheeks from the alveolar processes of the maxillæ and mandible.

Fig. 196.—The floor of the pharynx of a human embryo about twenty-six days old. (From a model by K. Peter.)

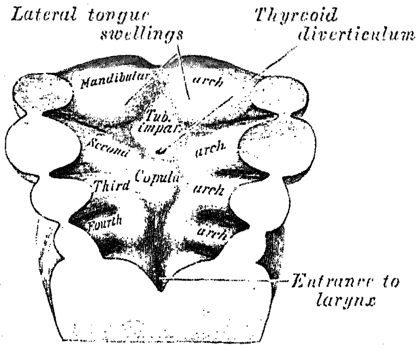
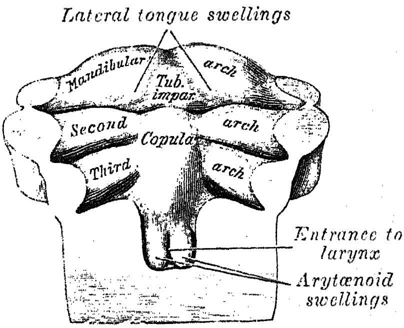
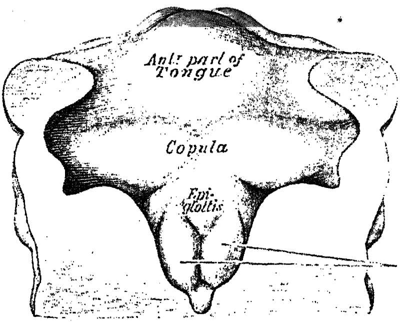


Fig. 197.—The floor of the pharynx of a human embryo about the end of the fourth week. (From a model by K. Peter.)



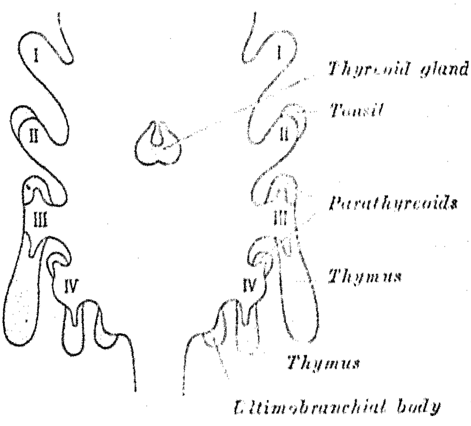
The **salivary glands** arise as buds from the epithelial lining of the mouth; the parotid appears during the fourth week in the angle between the maxillary process and the mandibular arch; the submaxillary appears in the sixth week, and the sublingual during the ninth week, in the hollow between the tongue and the mandibular arch.

FIG. 198.—The floor of the pharynx of a human embryo, about thirty days old. (From a model by K. Peter.)



The **tongue** (figs. 196 to 198) consists of an anterior or buccal and a posterior or pharyngeal part. During the third week there appears, immediately behind the ventral ends of the halves of the mandibular arch, a rounded swelling named the *tuberculum impar*, which was described by His as forming the whole of the buccal part of the tongue. More recent researches have shown that this part of the tongue is mainly, if not entirely, developed from a pair of lateral lingual swellings which arise from the inner surface of the mandibular arch and meet in the middle line. The tuberculum impar is said to form the central part of the tongue immediately in front of the foramen cæcum, but Hammar insists that it is purely a transitory structure and forms no part of the adult tongue. From the ventral ends of the fourth arch there arises a second and larger elevation, in the centre of which is a median groove or furrow. This elevation, named by His the *furcula*, is at first separated from the tuberculum impar by a depression, but later by a ridge, the *copula*, formed by the forward growth and fusion of the ventral ends of the second and third arches. The posterior or pharyngeal part of the tongue is developed from the copula, which extends forwards in the form of a V, so as to embrace between its two limbs the buccal part of the tongue. At the apex of the V a pit-like invagination occurs, to form the thyreoid gland, and this depression is represented in the adult by the *foramen cæcum* of the tongue. In the adult the union of the anterior and posterior parts of the tongue is marked by the V-shaped *sulcus terminalis*, the apex of which is at the foramen cæcum, while the two limbs run lateralwards and forwards parallel to but a little behind the papillæ vallatæ.

FIG. 199.—A scheme showing the development of the branchial epithelial bodies. (Modified from Kohn.)



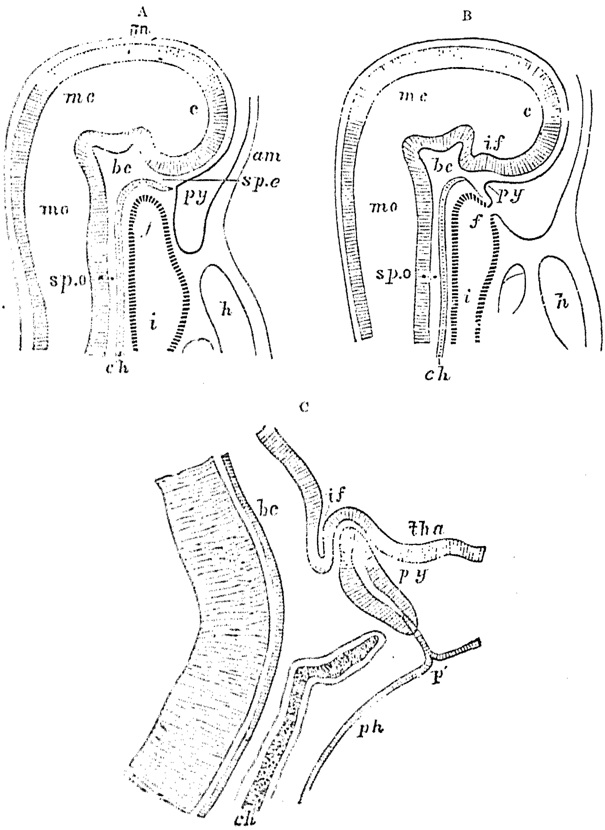
I, II, III, IV. Pharyngeal pouches.

The **thyreoid gland** is developed from a median diverticulum, which appears about the fourth week on the summit of the tuberculum impar, but later is found in the furrow immediately behind the tuberculum (fig. 196). It grows downwards and backwards as a tubular duct, which bifurcates and subsequently divides into a series of cellular cords, from which the isthmus and lateral lobes of the thyreoid gland are developed. As already stated (p. 78), the ultimobranchial bodies from the fifth pharyngeal pouches are enveloped by the lateral lobes of the thyreoid gland, but they undergo atrophy and do not form true thyreoid tissue. The connexion of the diverticulum with the pharynx is termed the *thyreoglossal duct*; by the second month the duct is obliterated, its upper end being represented by the foramen cæcum of the tongue, and its lower by the pyramidal lobe of the thyreoid gland.

The **palatine tonsils** are developed from the parts of the second pharyngeal

pouches which lie between the tongue and the soft palate. The entoderm lining these pouches grows in the form of a number of solid buds into the surrounding mesoderm. These buds are excavated by the degeneration and shedding of their central cells, and by this means the tonsillar crypts are formed. Lymphoid cells accumulate around the crypts, and are grouped to form the lymphoid follicles. The supratonsillar fossa is a remnant of the second pharyngeal pouch.

FIG. 200.—Sagittal sections of the heads of early embryos of the rabbit. Magnified. (From Mihalkovics.)



A. From an embryo of 5 mm. long. B. From an embryo of 6 mm. long. C. Vertical section of the anterior end of the notochord and hypophysis, etc., from an embryo 16 mm. long. In A the bucco-pharyngeal membrane is still present. In B it is in the process of disappearing, and the stomodæum now communicates with the primitive pharynx. *am.* Amnion. *c.* Fore-brain. *ch.* Notochord. *f.* Anterior extremity of fore-gut, *i.* *h.* Heart. *if.* Infundibulum. *m.* Wall of brain cavity. *mc.* Mid-brain. *mo.* Hind-brain. *p.* Original position of hypophysial diverticulum, *py.* *ph.* Pharynx. *sp.e.* Spheno-ethmoidal, *bc.* Central, and *sp.o.* Spheno-occipital parts of basis cranii. *tha.* Thalamus.

The **thymus** appears in the form of two flask-shaped entodermal diverticula, which arise, one on either side, from the third pharyngeal pouch (fig. 199), and extend lateralwards and backwards into the surrounding mesoderm in front of the ventral aortæ. Here they meet and are subsequently joined by connective tissue, but there is never any fusion of the thymus tissue proper. The pharyngeal opening of each diverticulum is soon obliterated, but the stalk persists for some time as a cellular cord. By further proliferation of the cells lining the diverticulum, buds of cells are formed, which become surrounded and isolated by the invading mesoderm. In the latter, numerous lymphoid cells make their appearance, and are aggregated to form lymphoid follicles. These lymphoid cells are probably derivatives of the entodermal cells which lined the original diverticula and their subdivisions. Additional portions of thymus tissue are sometimes developed from the fourth branchial pouches. The thymus begins to atrophy about the age of puberty.

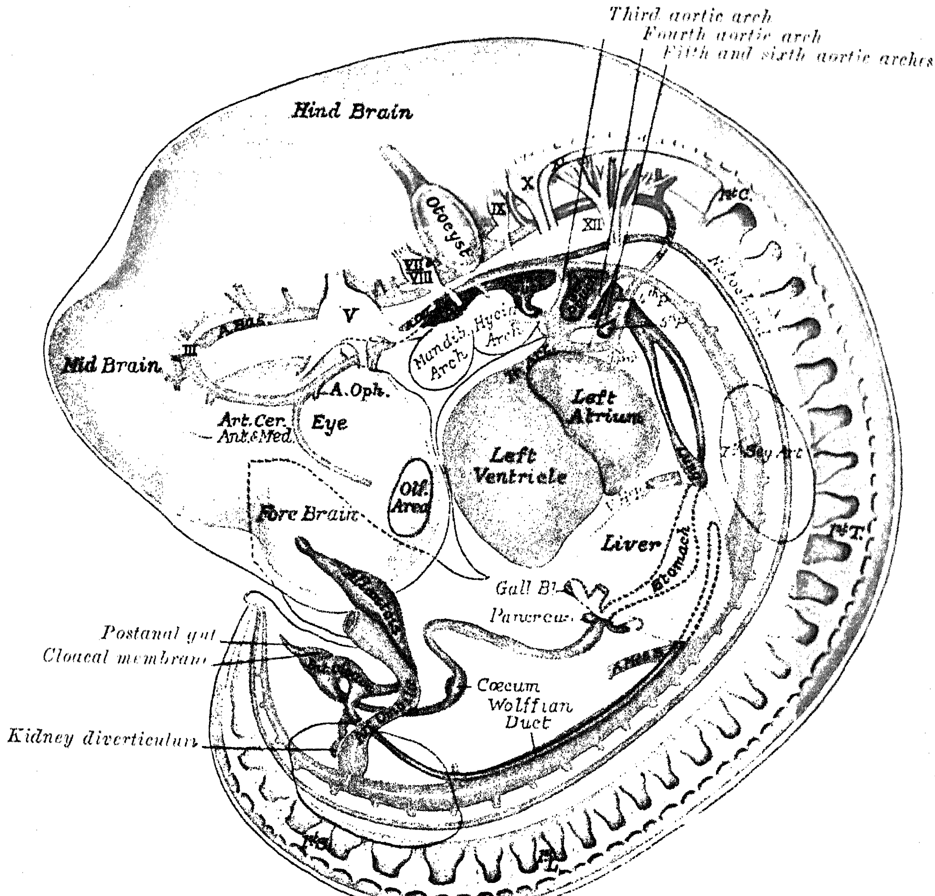
The two pairs of **parathyreoid bodies** are developed as outgrowths from the third and fourth pharyngeal pouches (fig. 199); the diverticula from the third pouches, being attached to the stalks of the thymus, are drawn to a lower level than those from the fourth pouches, and consequently the inferior pair of parathyreoids is derived from the third, and the superior pair from the fourth, pharyngeal pouches.

Two diverticula arise from the fifth pharyngeal pouches and form what are termed the *ultimobranchial bodies* (fig. 199); the latter fuse with the thyreoid gland, but do not form true thyreoid tissue.

The **hypophysis cerebri** consists of an anterior and a posterior lobe; the former is derived from the ectoderm of the stomodæum, the latter from the floor of the fore-brain. Previous to the rupture of the buccopharyngeal membrane a pouch-like diverticulum of the ectodermal lining of the roof of the stomodæum

appears. This diverticulum (*pouch of Rathke*) (fig. 200) is the rudiment of the anterior lobe of the hypophysis; it extends upwards in front of the cephalic end of the notochord and in front of the buccopharyngeal membrane, and comes into contact with the under surface of the fore-brain. It is then constricted off to form a closed vesicle, but remains for a time connected to the ectoderm of the stomodæum by a solid cord of cells. Masses of epithelial cells form on either side and in the front wall of the vesicle, and by the growth of a stroma from the mesoderm between the masses the development of the anterior lobe of the hypophysis is completed. A

FIG. 201.—A human embryo of 7 mm. greatest length. Left lateral aspect. (From a reconstruction by P. Thompson.)

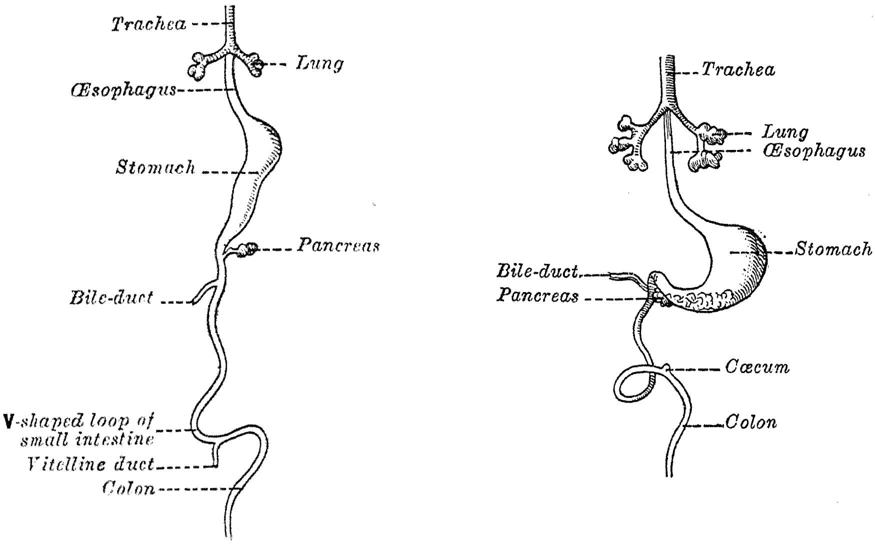


canal (*craniopharyngeal canal*) sometimes runs from the anterior part of the fossa hypophyseos of the sphenoidal bone to the under surface of the skull, and marks the original position of Rathke's pouch; while at the junction of the septum of the nose with the palate traces of the stomodæal end of the pouch are occasionally present (Frazer). The stomodæal part of the hypophysis becomes applied to the anterolateral aspect of a downwardly directed diverticulum from the base of the fore-brain (p. 95). This diverticulum constitutes the future infundibulum of the floor of the third ventricle, and its inferior extremity is modified to form the posterior lobe of the hypophysis. In some of the lower animals the posterior lobe contains nerve-cells and nerve-fibres, but in man and the higher vertebrates these are replaced by connective tissue.

A small entodermal diverticulum, termed *Seessel's pouch*, projects towards the brain from the anterior end of the foregut, close to the buccopharyngeal membrane. In some marsupials this pouch forms a part of the hypophysis (pituitary body).

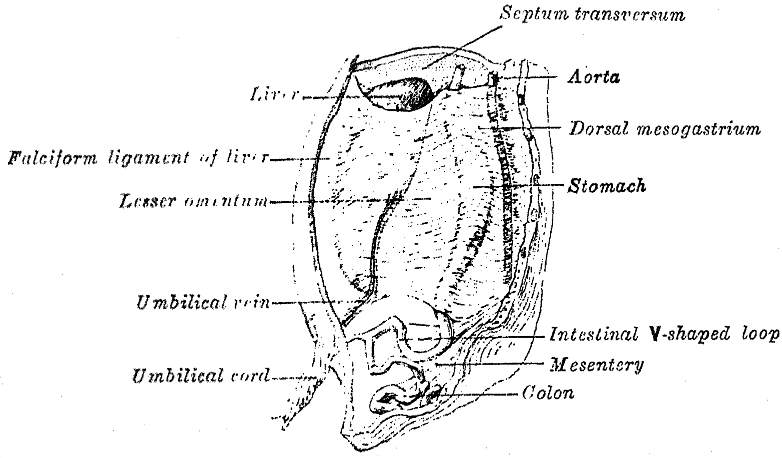
The **further development of the digestive tube.**—The upper part of the fore-gut dilates to form the pharynx (fig. 194) in the lateral walls of which the branchial arches are developed (p. 76); the succeeding part remains tubular, and is elongated

FIG. 202.—Front views of two successive stages in the development of the digestive tube. (His.)



to form the œsophagus. About the fourth week a fusiform dilatation, the future stomach, makes its appearance (fig. 201), and beyond this the gut opens into the yolk-sac; this opening is at first wide, but is gradually narrowed into a tubular stalk, the *yolk-stalk* or *vitelline duct.* Between the stomach and the mouth of the yolk-sac the liver diverticulum appears. From the stomach to the rectum the alimentary canal is attached to the notochord by a band of mesoderm, from which the common mesentery of the gut is subsequently developed. The stomach has an additional attachment to the anterior abdominal wall as far as

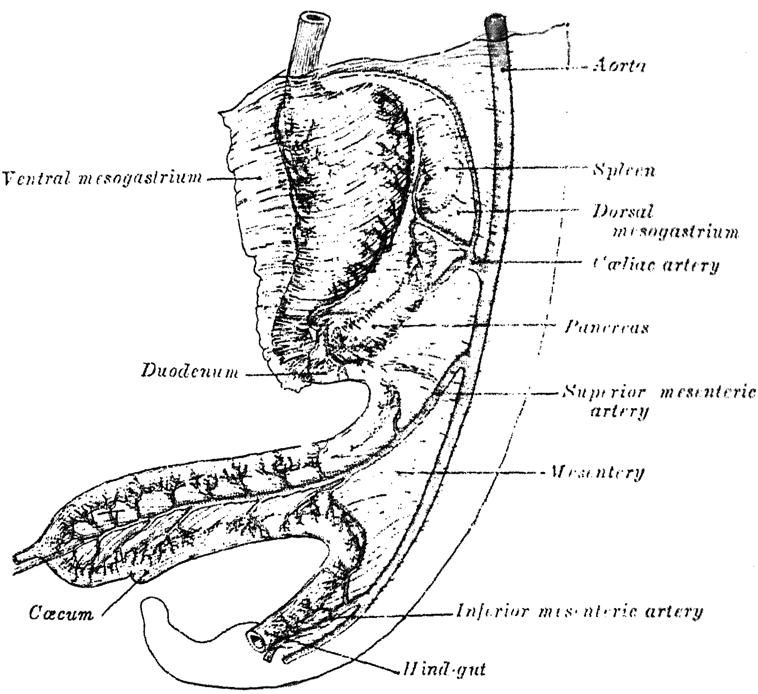
FIG. 203.—The primitive mesentery of a human embryo, six weeks old. Half-schematic. (Kollmann.)



the umbilicus by the septum transversum. The cephalic portion of the septum transversum takes part in the formation of the Diaphragm, while the caudal portion into which the liver grows forms the *ventral mesogastrium* (fig. 203). The

stomach undergoes a further dilatation, and its two curvatures can be recognised (fig. 202), the greater directed towards the vertebral column and the lesser towards the anterior wall of the abdomen, while its two surfaces look to the right and left respectively. Distal to the stomach the gut undergoes great elongation, and forms a V-shaped loop which projects downwards and forwards; from the bend or angle of the loop the vitelline duct opens (fig. 203). For a time a large part of the loop extends beyond the abdominal cavity into the umbilical cord, but by the end of the third month it is withdrawn within the cavity. With the lengthening of the tube, the mesoderm, which attaches it to the future vertebral column and carries the blood vessels for the supply of the gut, is thinned and drawn out to form the *posterior common mesentery*. The portion of this mesentery attached to the greater curvature of the stomach is named the *dorsal mesogastrium*, and the part which

FIG. 204.—The abdominal part of the digestive tube and its attachment to the posterior common mesentery. From a human embryo, six weeks old. (After Toldt.) (From Kollmann's Entwickelungsgeschichte.)



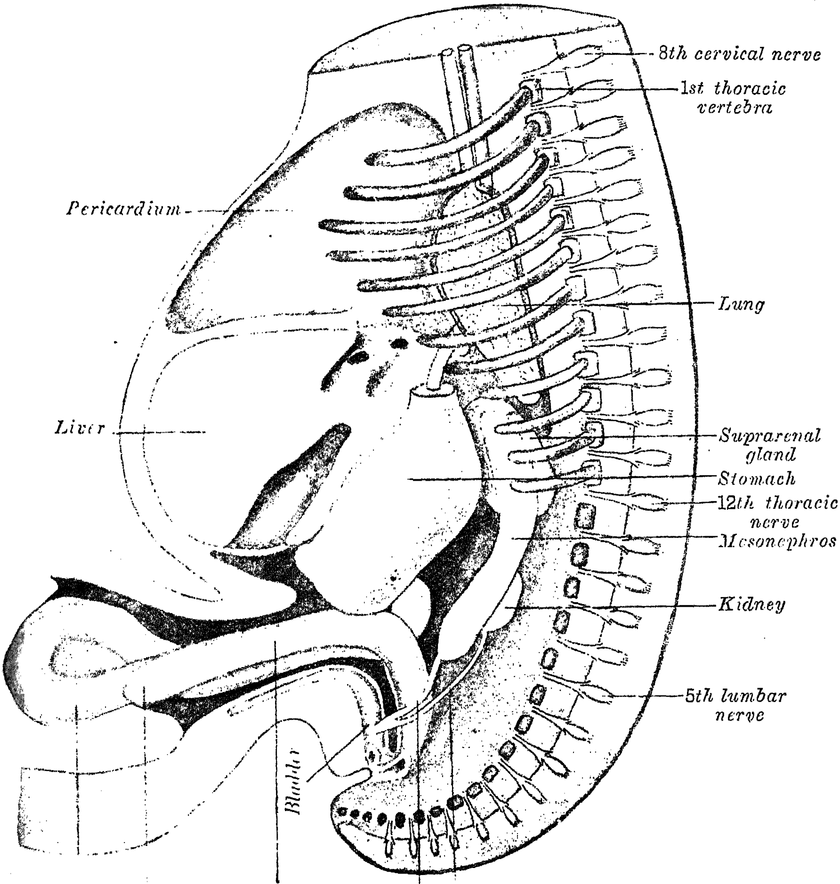
suspends the intestine is termed the *mesentery* (fig. 204). About the sixth week a diverticulum of the gut appears just behind the opening of the vitelline duct, and is differentiated into the future cæcum and vermiform process. The part of the loop on the distal side of the cæcal diverticulum increases in diameter and forms the future ascending and transverse portions of the large intestine. Until the fifth month the cæcal diverticulum has a uniform calibre, but from this time onwards its distal part remains rudimentary and forms the vermiform process, while its proximal part expands to form the cæcum. Further changes are meanwhile taking place in the shape and position of the stomach. The fundus is developed as a localised outgrowth or diverticulum from the cardiac end of the greater curvature.* Lewis † points out that in a 16 mm. embryo a canal (gastric canal) passes along the lesser curvature of the stomach from the œsophagus to the pars pylorica, and that in a 44·3 mm. embryo this canal is more distinct than in the earlier stages and reaches from the antrum cardiacum to the incisura angularis.

* A. Keith and F. Wood Jones, *Proceedings of the Anatomical Society of Great Britain and Ireland*, November 1901.

† F. T. Lewis, *American Journal of Anatomy*, vol. xiii. 1912.

The dorsal part or greater curvature of the stomach, to which the dorsal mesogastrium is attached, grows much more rapidly than its ventral part or lesser curvature, to which the ventral mesogastrium is fixed. The dorsal mesogastrium expands rapidly, and the greater curvature is carried downwards and to the left, and the right surface of the stomach is now directed backwards, and the left surface forwards (fig. 206)—a change in position which explains why the left vagus nerve is found on the front, and the right vagus on the back of the

FIG. 205.—The trunk of a human embryo 17 mm. long. (After a reconstruction by Mall.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



stomach. The dorsal mesogastrium attached to the greater curvature follows its alterations in position, and hence it is greatly elongated and drawn to the left and ventralwards, and, as in the case of the stomach, the right surfaces of both the dorsal and ventral mesogastria are now directed backwards, and the left forwards. In this way a pouch, the *bursa omentalis*, is formed behind the stomach, and this increases in size as the digestive tube undergoes further development; the entrance to the pouch constitutes the future *epiploic foramen* (foramen of Winslow).

The duodenum is developed from that part of the tube which immediately succeeds the stomach; it undergoes little elongation, being more or less fixed in position by the liver and pancreas, which arise as diverticula from it; for a time its lumen is occluded by an epithelial plug. The duodenum is at first suspended by a mesentery, and projects forwards in the form of a loop; but the loop and its mesentery are subsequently displaced by the transverse colon, so that the right surface of the duodenal mesentery is directed backwards, and, adhering to the

parietal peritoneum, is lost. The remainder of the digestive tube elongates greatly, and is thrown into coils, and this elongation demands a corresponding

Fig. 206.—Diagrams to illustrate two stages in the development of the digestive tube and its mesentery. The arrow indicates the entrance to the bursa omentalis.

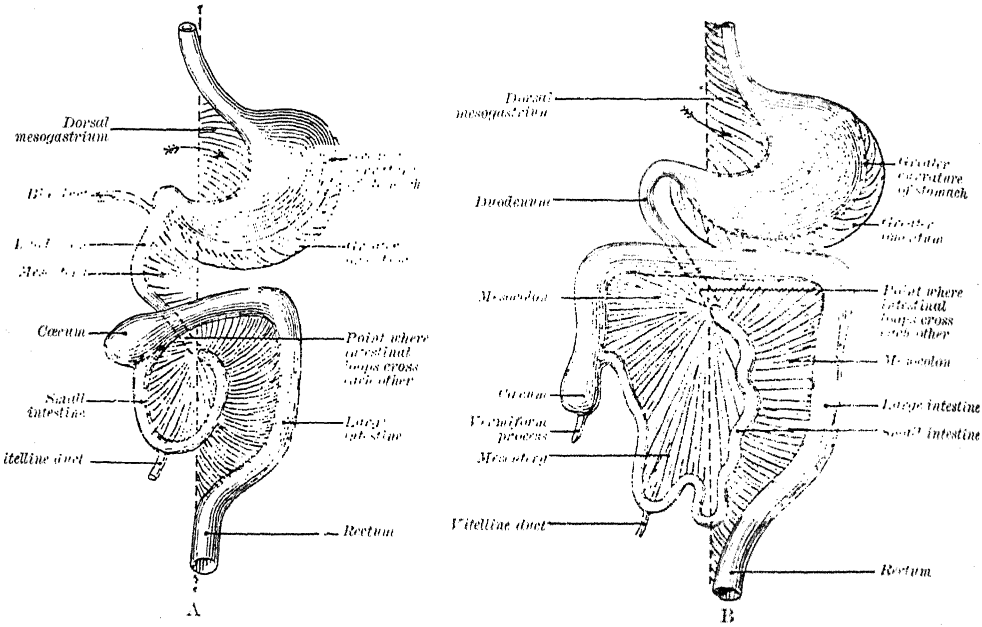
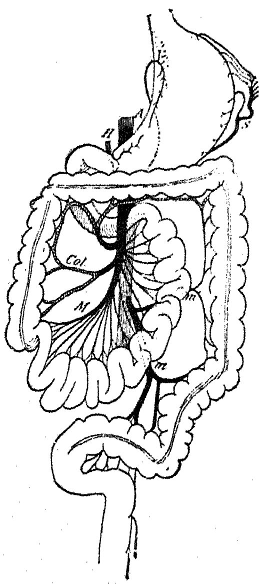
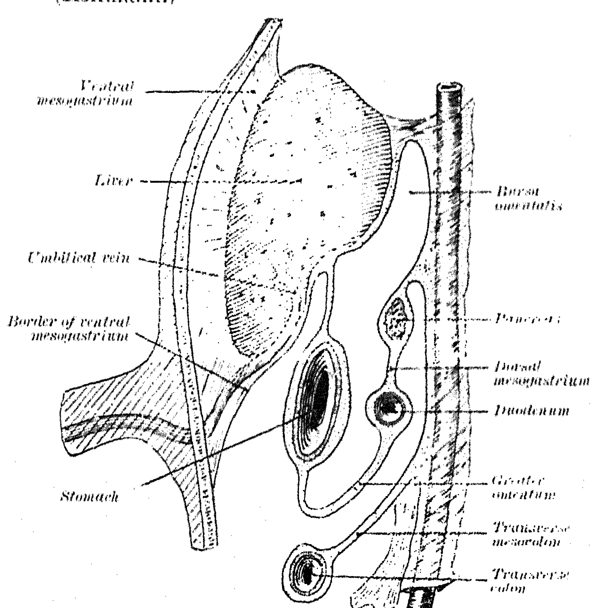


Fig. 207.—The final disposition of the intestines and their vascular relations. (Jonnesco.)



A, Aorta. *H*. Hepatic artery. *M*, *Col*. Branches of superior mesenteric artery. *m*, *m'*. Branches of inferior mesenteric artery. *S*. Lienal artery.

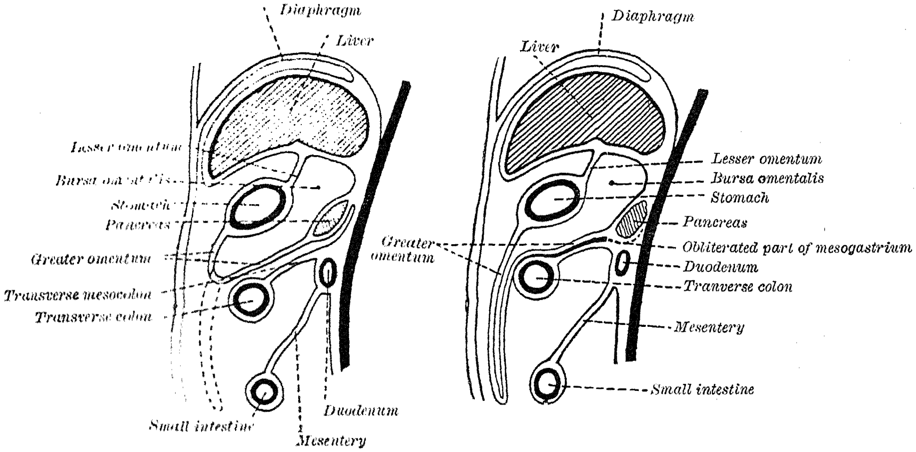
Fig. 208.—A schematic figure of the bursa omentalis, &c. From a human embryo, eight weeks old. (Kollmann.)



increase in the width of the intestinal attachment of the mesentery, which becomes folded.

At this stage the small and large intestines are attached to the vertebral column by a common mesentery, the coils of the small intestine falling to the right of the middle line, while the large intestine lies on the left side.*

Fig. 209.—Diagrams to illustrate the development of the greater omentum and the transverse mesocolon.



The gut is now rotated upon itself, so that the large intestine is carried over in front of the small intestine, and the cæcum is placed immediately below the liver; about the sixth month the cæcum descends into the right iliac fossa, and the large intestine forms an arch consisting of the ascending, transverse, and descending portions of the colon—the transverse portion crossing in front of the duodenum and lying just below the greater curvature of the stomach; within this arch the coils

Fig. 210.—The tail-end of a human embryo, fifteen to eighteen days old. (From a model by Keibel.)

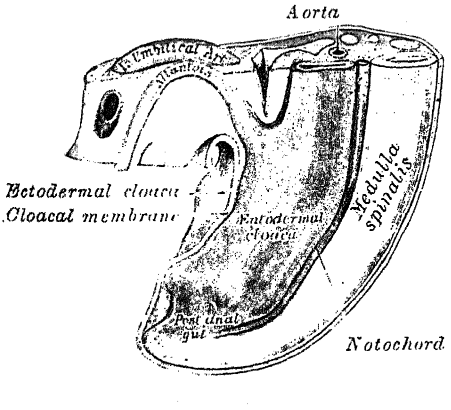
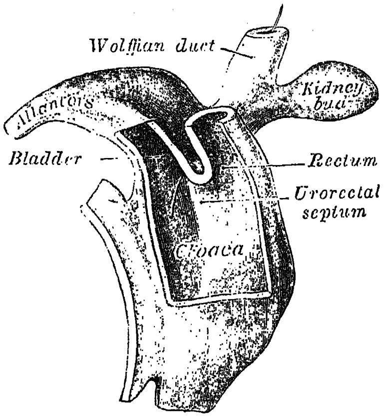


Fig. 211.—The cloaca of a human embryo, twenty-five to twenty-seven days old. (From a model by Keibel.)



of the small intestine are disposed (fig. 207). Sometimes the downward progress of the cæcum is arrested, so that in the adult it may be found lying immediately below the liver instead of in the right iliac region.†

* Sometimes this condition persists throughout life, and the duodenum lies entirely on the right side of the median plane, where it is continued into the jejunum; in such cases the arteries to the small intestine (jejunal and ileal) arise from the right instead of the left side of the superior mesenteric artery.

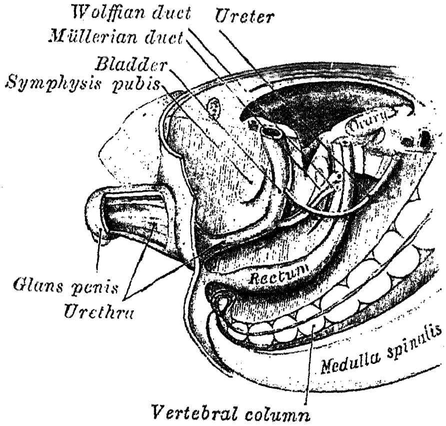
† See article by J. Ernest Frazer and R. H. Robbins 'On the factors concerned in causing rotation of the intestine in man,' *Journal of Anatomy and Physiology*, vol. L.

Further changes take place in the bursa omentalis and in the common mesentery, and give rise to the peritoneal relations seen in the adult. The bursa omentalis, which at first reaches only as far as the greater curvature of the stomach, extends downwards in front of the transverse colon and the coils of the small intestine to form the greater omentum (fig. 208). Before the pleuroperitoneal opening is closed, the bursa omentalis sends a diverticulum upwards on either side of the œsophagus; the left diverticulum soon disappears, but the right is constricted off and forms the *bursa infracardiaca* which may persist in the adult as a small sac lying within the thorax on the right side of the lower end of the œsophagus. The anterior layer of the transverse mesocolon is at first distinct from the posterior layer of the greater omentum, but the two layers blend, and then the greater omentum becomes attached to the transverse colon (fig. 209). The mesenteries of the ascending and descending parts of the colon disappear in the majority of cases, while that of the small intestine assumes the oblique attachment characteristic of its adult condition.

The lesser omentum is formed, as indicated above, by a thinning of the mesoderm (*ventral mesogastrium*) which attaches the stomach and duodenum to the anterior abdominal wall. By the subsequent growth of the liver this leaf of mesoderm is divided into two parts, viz. the lesser omentum between the stomach and liver, and the falciform and coronary ligaments between the liver and the abdominal wall and Diaphragm (figs. 203, 208).

The **rectum and anal canal.**—The hind-gut is at first prolonged backwards into the body-stalk as the tube of the allantois; but, with the growth and flexure of the tail-end of the embryo, the body-stalk, with its contained allantoic tube, is carried forwards to the ventral aspect of the body, and consequently a bend is formed at the junction of the hind-gut and allantois. This bend dilates to form a pouch, which constitutes the *entodermal cloaca*; into its dorsal part the hind-gut opens, and from its ventral part the allantois passes into the body-stalk. At a later stage the Wolffian and Müllerian ducts open into the ventral portion of the cloaca. The cloaca is, for a time, shut off from the exterior by the *cloacal membrane* which is formed by the apposition of a thick ectodermal and a thin entodermal layer, and reaches at first as far forwards as the future umbilicus. Behind the umbilicus, however, the mesoderm subsequently extends to form the symphysis pubis and the lower part of the abdominal wall. By the growth of the surrounding tissues the cloacal membrane comes to lie at the bottom of a depression, which is lined by ectoderm and named the *ectodermal cloaca* (fig. 210)

Fig. 212.—The tail-end of a human embryo, eight and a half to nine weeks old. (From a model by Keibel.)

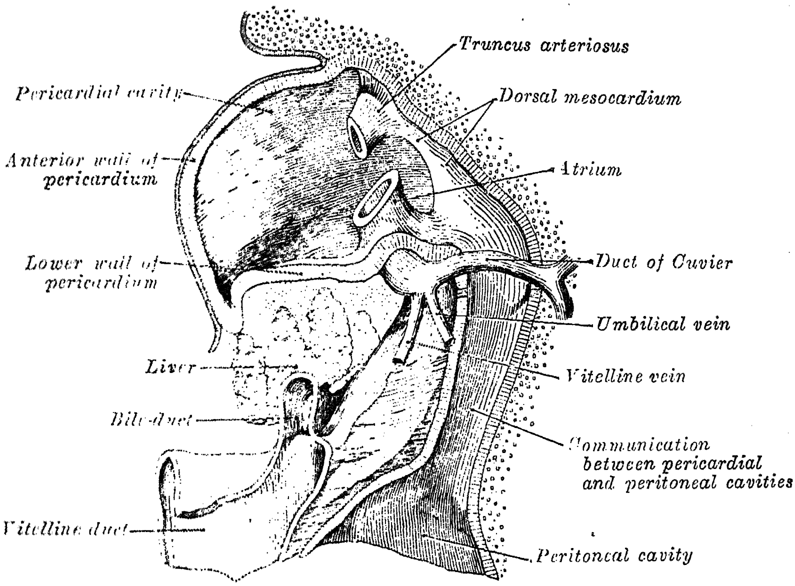


The entodermal cloaca is divided into a narrow dorsal and a wide ventral part by means of a partition, the *urorectal septum* (fig. 211). This septum grows downwards from the ridge separating the allantoic from the cloacal opening of the intestine and, fusing with the cloacal membrane, divides the latter into an anal and a urogenital membrane. The dorsal part of the cloaca forms the rectum, and the anterior part the urogenital sinus and bladder. For a time a communication named the *cloacal duct* exists between the two parts of the cloaca below the urorectal septum; this duct occasionally persists as a passage between the rectum and the bladder or urethra. By the upgrowth of the surrounding parts the anal part of the cloacal membrane comes to lie at the bottom of a depression, the *proctodæum* or *anal pit*. On the absorption and disappearance of this membrane the rectum communicates with the anal canal (fig. 212). A small part of the hind-gut projects backwards beyond the anal membrane; it is named the *post-anal gut* (fig. 210), and usually becomes obliterated and disappears.*

* Consult in this connexion: 'A contribution to the morphology of the human urogenital tract,' by D. Berry Hart, *Journal of Anatomy and Physiology*, vol. xxxv.

The **liver** arises as a diverticulum from the ventral surface of the fore-gut at the point where the latter joins the yolk-sac (fig. 213). This diverticulum is lined with entoderm, and grows upwards and forwards into the septum transversum which is a mass of mesoderm between the vitelline duct and the pericardial cavity; the

FIG. 213.—The liver with the septum transversum. Human embryo. (After a model and figure by His.)



diverticulum gives off two solid buds of cells which represent the right and the left lobes of the liver. The solid buds of cells grow into columns or cylinders, termed the *hepatic cylinders*, which branch and anastomose to form a close meshwork. This network invades the vitelline and umbilical veins, and breaks them up into a series of capillary-like vessels termed *sinusoids* (Minot), which ramify in the meshes of the cellular network. By the continued growth and ramification of the hepatic cylinders the mass of the liver is gradually formed. The original diverticulum from the duodenum forms the bile-duct, and from this the cystic duct and gall-bladder

FIG. 214.—The pancreas of a human embryo, five weeks old. (Kollmann.)

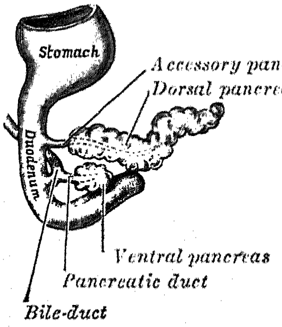
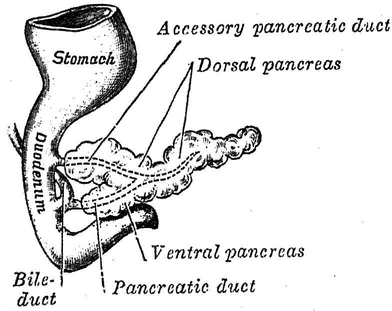


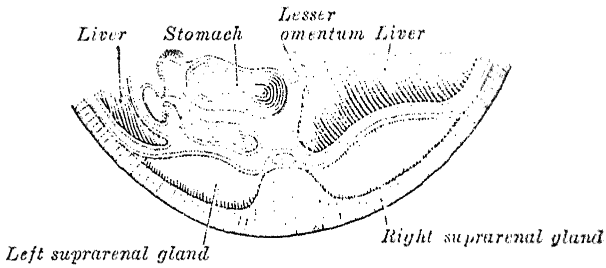
FIG. 215.—The pancreas of a human embryo, at the end of the sixth week. (Kollmann.)



arise as a solid outgrowth which later acquires a lumen. The opening of the bile-duct is at first in the ventral wall of the duodenum; later, owing to the rotation of the gut the opening is carried to the left and then dorsalwards to the position it occupies in the adult.

As the liver undergoes enlargement, both it and the ventral mesogastrium are gradually differentiated from the septum transversum; and from the under surface of the latter the liver projects downwards into the abdominal cavity. By the growth of the liver the ventral mesogastrium is divided into two parts, of which the anterior forms the falciform and coronary ligaments and the posterior the lesser omentum. About the third month the liver almost fills the abdominal cavity, and its left lobe is nearly as large as its right. From this period the relative development of the liver is less active, more especially that of the left lobe, which

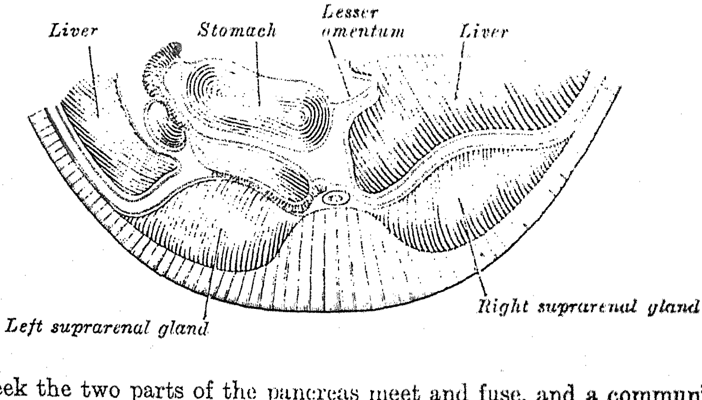
Fig. 216.—A schematic and enlarged transverse section through the body of a human embryo, in the region of the mesogastrium. At the beginning of the third month. (Modified from Toldt.)



actually undergoes some degeneration and becomes smaller than the right; but up to the end of fœtal life the liver remains relatively larger than in the adult.

The **pancreas** (figs. 214, 215).—The pancreas is developed in two parts, a dorsal and a ventral. The former arises as a diverticulum from the dorsal wall of the duodenum a short distance above the hepatic diverticulum, and, growing upwards and backwards into the dorsal mesogastrium, forms the whole of the body and tail of the pancreas and a part of the head and uncinate process. The ventral part appears in the form of a diverticulum from the primitive bile-duct at the spot where the latter opens into the duodenum; from the ventral pancreas the remainder of the head and uncinate process of the pancreas are developed. The duct of the dorsal part (accessory pancreatic duct) therefore opens directly into the duodenum, while that of the ventral part (pancreatic duct) opens with the bile-duct. About

Fig. 217.—A schematic and enlarged transverse section through the same region as in fig. 216, at end of the third month. (Modified from Toldt.)

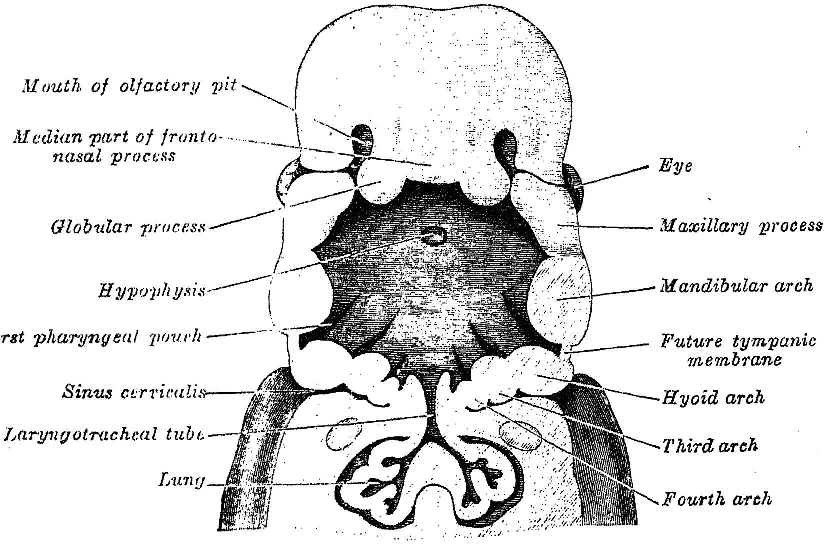


the sixth week the two parts of the pancreas meet and fuse, and a communication is established between their ducts. After this has occurred the terminal part of the accessory duct, i.e. the part between the duodenum and the point of meeting of the two ducts, undergoes little or no enlargement, while the duct of the ventral part increases in size and forms the main duct of the gland. The opening of the accessory duct into the duodenum is sometimes obliterated, and even when it remains patent it is probable that the whole of the pancreatic secretion is conveyed through the pancreatic duct.

At first the pancreas is directed upwards and backwards between the two layers of the dorsal mesogastrium, which give to it a complete peritoneal investment, and its surfaces look to the right and left. With the change in the position of the stomach the dorsal mesogastrium is drawn downwards and to the left, and the right side of the pancreas is directed backwards, and the left forwards (fig. 216). The right surface becomes applied to the posterior abdominal wall, and the peritoneum which covers it undergoes absorption (fig. 217); and thus, in the adult, the gland lies behind the peritoneal cavity.

The **spleen** (fig. 204).—Although the spleen belongs to the group of ductless glands, its development may be conveniently referred to here. It appears about the fifth week as a localised thickening of the mesoderm in the dorsal mesogastrium above the tail of the pancreas. With the change in position of the stomach the spleen is carried to the left, and comes to lie behind the stomach and in contact with the left kidney. The part of the dorsal mesogastrium which intervened between the spleen and the greater curvature of the stomach forms the gastrosplenic ligament (gastrosplenic omentum).

Fig. 218.—The head and neck of a human embryo thirty-two days old. Ventral aspect. The floor of the mouth and the ventral wall of the pharynx have been removed. (His.)



The **respiratory organs.**—The rudiment of the respiratory organs appears in the fourth week as a median *laryngotracheal groove* in the ventral wall of the pharynx. The groove deepens and its lips fuse to form a septum which grows from below upwards and converts the groove into a tube, the *laryngotracheal tube* (fig. 218), the cephalic end of which opens into the pharynx by a slit-like aperture formed by the persistent anterior part of the groove. The tube is lined with entoderm, and from this the epithelial lining of the respiratory tract is developed. The cephalic part of the tube forms the larynx, and its next succeeding part the trachea, while from its caudal end two lateral outgrowths, the right and left *lung-buds*, arise, and from the mesoderm surrounding them the connective tissue of the bronchi and lungs are developed.

The first rudiment of the larynx consists of two *arytænoid swellings*, which appear, one on either side of the cephalic end of the laryngotracheal groove, and are continuous in front of the groove with a transverse ridge (*furcula* of His) which lies between the ventral ends of the fourth branchial arches and from which the epiglottis is subsequently developed (figs. 197, 198). After the separation of the trachea from the œsophagus, the arytænoid swellings come into contact with one another and with the back of the epiglottis, and the entrance to the larynx assumes the form of a T-shaped cleft, the margins of the cleft adhere to one another and the laryngeal entrance is for a time occluded. The

arytænoid swellings are differentiated into the arytænoid and corniculate cartilages, and the folds joining them to the epiglottis form the aryepiglottic folds in which the cuneiform cartilages are developed as derivatives of the epiglottis. The thyreoid cartilage is developed from the ventral ends of the cartilages of the fourth and fifth branchial arches; it appears as two lateral plates, each chondrified from two centres and united in the midventral line by membrane in which an additional centre of chondrification develops. The cricoid cartilage arises from two cartilaginous centres, which soon unite ventrally and gradually extend and ultimately fuse on the dorsal aspect of the tube.*

According to Frazer,† who has made an important investigation on the development of the larynx, the glottis or space between the vocal folds is the primary opening of the larynx. During the second and third months a lateral mass (arytænoid swelling), derived from the fourth and fifth arches, grows forward on either side

FIG. 219.—The lung-buds from a human embryo, about four weeks old, showing commencing lobulation. (His.)

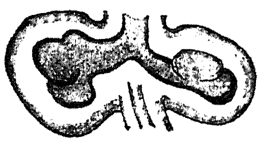
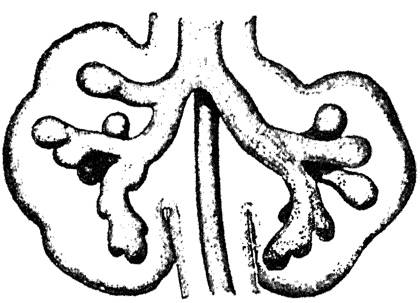


FIG. 220.—The lungs of a human embryo more advanced in development. (His.)



of the primary opening, and from these masses the lateral walls of the vestibule of the larynx are developed. A third elevation or 'central mass' is formed behind the second and third arches. These three masses bound the secondary opening of the larynx. In the lateral masses the arytænoid cartilages and aryepiglottic folds are developed; from the central mass the epiglottis is formed.

The right and left lung-buds grow out posterior to the ducts of Cuvier, and divide into lobules, three appearing on the right, and two on the left, lung-bud; these subdivisions are the early indications of the corresponding lobes of the lungs (figs. 219, 220). The buds undergo further subdivision and ramification, and ultimately end in minute expanded extremities—the infundibula of the lung. After the sixth month the air-sacs begin to make their appearance on the infundibula in the form of minute pouches. The pulmonary arteries are derived from the sixth aortic arches. During the course of their development the lungs migrate in a caudal direction, so that by the time of birth the bifurcation of the trachea is opposite the fourth thoracic vertebra. As the lungs grow they project into the pleural passages or parts of the cœlom which will ultimately form the pleural sacs, and the splanchnic mesoderm enveloping the lung rudiment expands on the growing lung and is converted into the pulmonary pleura.

THE DEVELOPMENT OF THE BODY-CAVITIES

In the human embryo described by Peters the mesoderm outside the embryonic disc is split into two layers enclosing the extra-embryonic part of the cœlom. Clefts appear in the embryonic part of the mesoderm, and fuse to form the intra-embryonic part of the cœlom. At first the two parts of the cœlom are separated from one another, but later they become continuous around the orifice of the future umbilicus, on the closure of which the continuity is again lost. The intra-embryonic part of the cœlom forms the pericardial, pleural and peritoneal cavities; the extra-

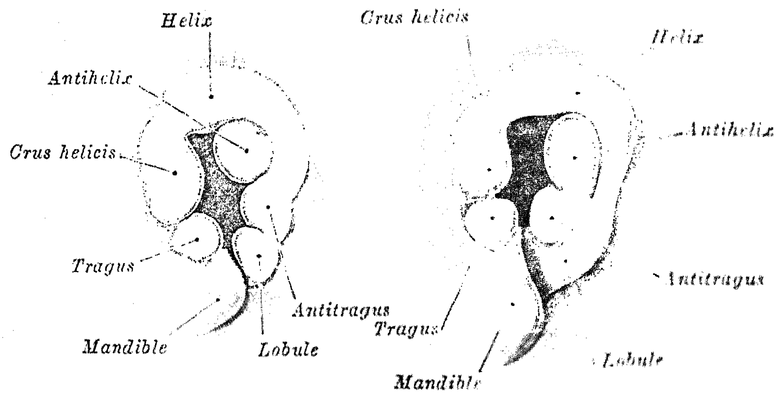
* E. Fawcett, *loc. cit.*

† J. Ernest Frazer, *Journal of Anatomy and Physiology*, vol. xliv.

area of the second arch includes the outer wall behind this, and turns on to the back wall to take in the tympanohyal region.' During the sixth or seventh month the tympanic antrum appears as an upward and backward expansion of the tympanic cavity.

The opinion generally held as to the development of the ossicles of the middle ear is that the *incus* and *malleus* are derived from the dorsal end of

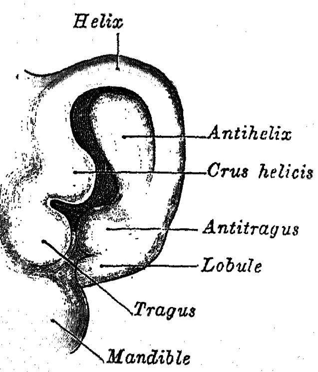
FIG. 161.—The left auriculæ of human embryos, estimated to be thirty-five and thirty-eight days old respectively. (After His.)



the mandibular (Meckel's) cartilage (fig. 116), the incus representing the quadrate bone of birds and reptiles. The *stapes* is developed from the dorsal end of the cartilage of the second or hyoid arch, and first appears as a ring (annulus stapedis) encircling a small vessel, the stapedial artery, which subsequently undergoes atrophy.

The external acoustic meatus is developed from the first branchial or outer pharyngeal groove. The lower part of this groove extends inwards as a funnel-shaped tube (primary meatus) from which the cartilaginous portion and a small part of the roof of the osseous portion of the meatus are developed. From the lower part of the funnel-shaped tube a solid epidermal plug extends downwards and inwards along the floor of the tubotympanic recess; by the breaking down of the central cells of this plug the inner part of the meatus (secondary meatus) is produced, while the deepest cells of the ectodermal plug form the epidermal stratum of the tympanic membrane. The fibrous stratum of the tympanic membrane is formed from the mesoderm which extends between the meatal plate and the entoderm of the floor of the tubotympanic recess.

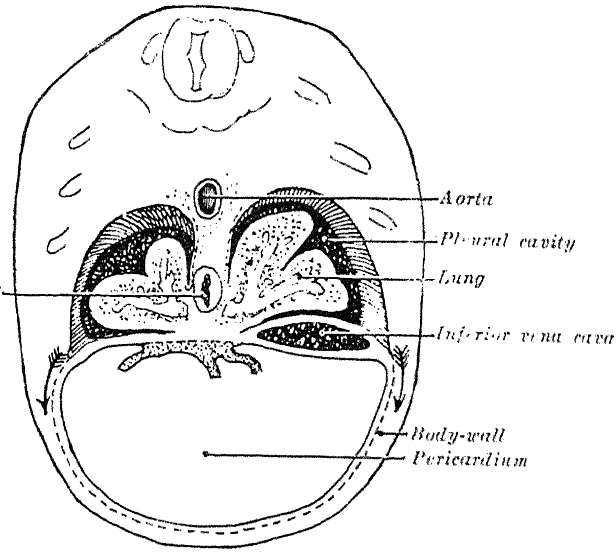
FIG. 162.—The auricula in a more advanced stage of development than those represented in fig. 161.



The auricula or pinna is developed by the gradual differentiation of six tubercles (fig. 160) which appear around the margin of the first branchial groove. Two tubercles appear on the posterior edge of the mandibular arch; these represent the rudiments of the tragus and crus helicis. Three are found on the hyoid arch, and indicate, from below upwards, the lobule, antitragus, and antihelix. One arises dorsal to the first branchial groove, and grows downwards behind the antitragus and antihelix; from it and its downward prolongation the helix is developed (figs. 161, 162). Some observers, however, maintain that the lowest tubercle on the hyoid arch becomes the antitragus, and that the lobule is developed later as an independent formation. The rudiment of the *acoustic nerve* appears about the end of the third week as the acoustic ganglion which is closely applied to the cephalic edge of the auditory vesicle; the cells of this ganglion are probably derived from the ectoderm

tissue; within it the liver is developed, and from it the principal part of the Diaphragm is formed. As development proceeds the dorsal end of the septum transversum is carried gradually caudalwards, and when it reaches the fourth cervical

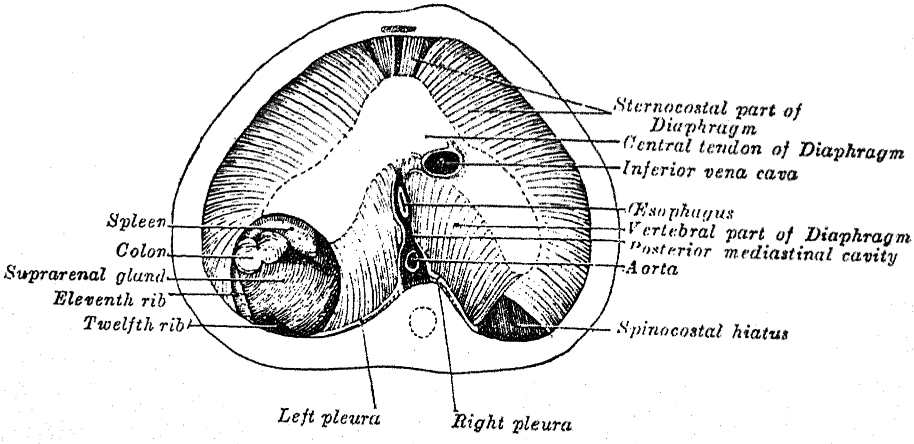
Fig. 223.—A diagram of a transverse section through a rabbit embryo. (After Keith.)



segment muscular tissue and the phrenic nerve grow into it. It continues to recede, however, until it reaches the position of the adult Diaphragm on the bodies of the upper lumbar vertebræ.

The lung-buds meanwhile grow out from the caudal end of the laryngotracheal tube (p. 145) into the pleural passages and distend these passages to form the pleural cavities (fig. 223). Those parts of the lungs which grow in an upward or cephalic direction pass on the lateral sides of the ducts of Cuvier, and gradually push these

Fig. 224.—The thoracic aspect of the Diaphragm of a new-born child in which the communication between the peritoneum and pleura has not been closed on the left side; the position of the opening is marked on the right side by the spinocostal hiatus. (After Keith.)



ducts and the mesoderm in which they lie against the pleuropericardial openings, with the result that the latter are soon reduced to mere slits (fig. 222). Owing to the descent of the dorsal end of the septum transversum the lung buds come to lie

above the septum, and thus pleural and peritoneal portions of the cœlom (still, however, in communication with one another) may be recognised.

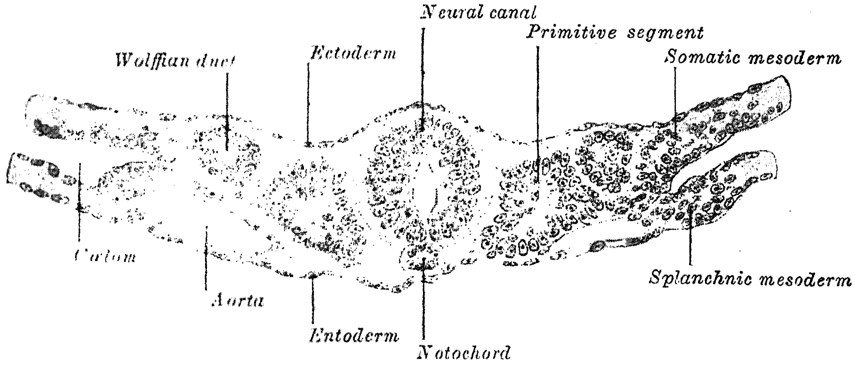
The ultimate separation of the pericardial, pleural, and peritoneal cavities from one another is effected by the growth of a ridge of tissue (*pulmonary ridge* of Mall) on either side from the mesoderm surrounding the duct of Cuvier (figs. 221, 222). The front or cephalic part of this ridge (pleuropericardial membrane) grows across and obliterates the pleuropericardial opening; the hinder or caudal part (pleuroperitoneal membrane) grows across the pleuroperitoneal opening. The pleuroperitoneal openings may remain patent; fig. 224 represents a persistent left opening, through which the spleen and left suprarenal body projected into the left pleural cavity.

With the continued growth of the lungs the pleural cavities are pushed forwards in the body-wall towards the ventral median line, thus separating the pericardium from the lateral thoracic walls (fig. 223). The further development of the peritoneal cavity has been described with the development of the digestive tube (p. 137 *et seq.*).

THE DEVELOPMENT OF THE UROGENITAL ORGANS

The urinary and generative organs are developed from the intermediate cell-mass which is situated between the primitive segments and the lateral plates of mesoderm. The permanent organs of the adult are preceded by a set of embryonic structures

FIG. 225.—A transverse section through a ferret embryo. (A. Robinson.)



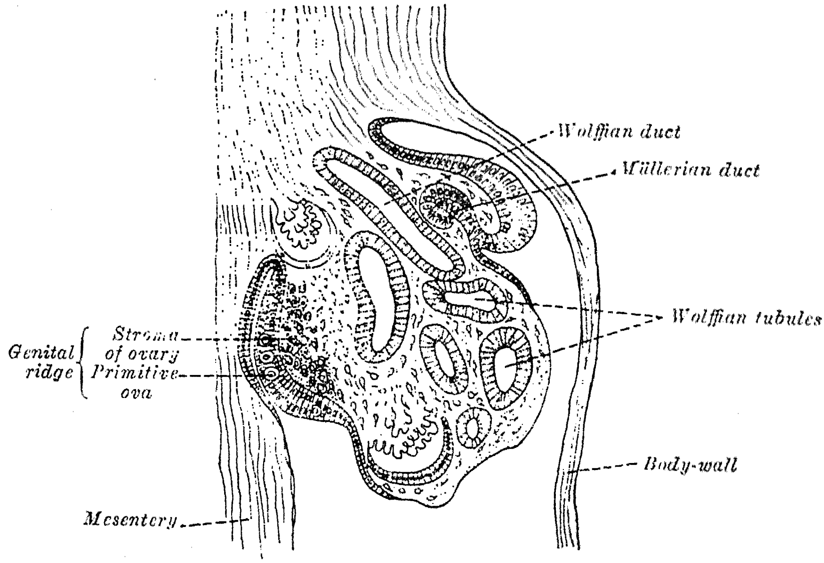
on either side; these consist of the pronephros, the mesonephros, the metanephros, and the Wolffian and Müllerian ducts. The pronephros disappears very early; the structural elements of the mesonephros mostly degenerate, but in their place is developed the genital gland, in association with which the Wolffian duct remains as the duct of the male genital gland, the Müllerian as that of the female; some of the tubules of the metanephros form part of the permanent kidney.

The **pronephros and the Wolffian duct.**—In the intermediate cell-mass of the lower thoracic and upper cervical segments short evaginations from the cœlom grow dorsalwards into each segment. The evaginations form a series of transverse tubules each of which communicates by means of a funnel-shaped ciliated opening with the cœlomic cavity, and in the course of each duct a glomerulus also is developed. Secondary glomeruli are formed, and the complete group constitutes the *pronephros*. The tubules of the pronephros undergo rapid atrophy and disappear. A solid rod of cells forms in the mesoderm of the lateral cell-mass, just under the ectoderm and overlying the pronephros. This rod grows caudalwards to reach the ventral part of the cloaca, and becoming canalised, forms the *Wolffian duct* (fig. 225). In lower vertebrates its head-end acts as a duct for the pronephros and is termed the *pronephric duct*, but in man this function is in abeyance as the pronephros is a rudimentary and very transitory structure, the proximal part of it undergoing atrophy while the distal part is still in process of formation.

The **mesonephros, Müllerian duct, and genital gland.**—On the medial side of the Wolffian duct, and extending from the sixth cervical to the third lumbar

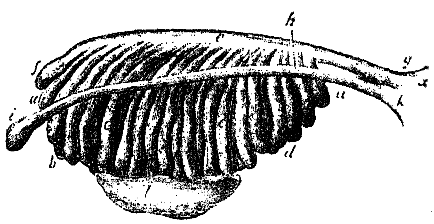
segment, the *Wolffian tubules* (fig. 226) are developed. Each tubule first appears as a solid mass of cells, which later becomes hollowed in the centre; one end grows towards and finally opens into the Wolffian duct, the other dilates and is invaginated by a tuft of capillary blood-vessels to form a glomerulus. The tubules collectively constitute the *mesonephros or Wolffian body* (figs. 201, 205, 227). By the fifth or

FIG. 226.—A section through the urogenital fold of a chick embryo, four days old. (Waldeyer.)



sixth week this body forms an elongated spindle-shaped structure, termed the *urogenital fold* (fig. 226), which projects into the cœlomic cavity on either side of the dorsal mesentery, from the septum transversum in front to the fifth lumbar segment behind; in the medial parts of these folds the genital glands are developed. The Wolffian bodies persist and form the permanent kidneys in fishes and amphibians, but in reptiles, birds, and mammals they atrophy and for the most part disappear coincidently with the development of the permanent kidneys. The atrophy begins during the sixth or seventh week of fœtal life and proceeds rapidly, so that by the beginning of the fifth month only the ducts and a few of the tubules remain.

FIG. 227.—The left Wolffian body before any distinction of sex has appeared. Anterior aspect. Enlarged. (From Farre, after Kobelt.)

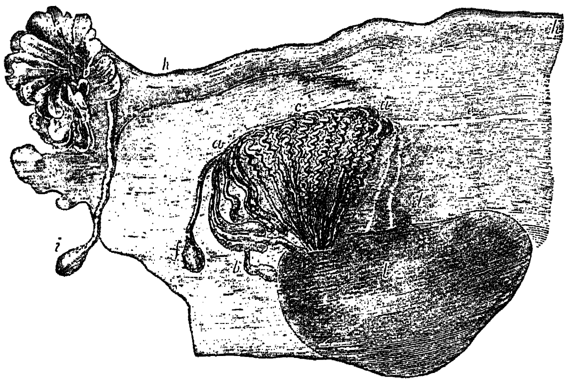


a, a, b, c, d. Tubular structure of the Wolffian body. *e.* Wolffian duct. *f.* Its upper extremity. *g.* Its termination in *x*, the urogenital sinus. *h.* Müllerian duct. *i.* Its upper, funnel-shaped extremity. *k.* Its lower end, terminating in the urogenital sinus. *l.* Genital gland. *x.* Urogenital sinus.

In the male the Wolffian duct persists, and forms the tube of the epididymis, the ductus deferens, and the ejaculatory duct; during the third month the seminal vesicle arises as a lateral diverticulum from the hinder end of the duct. A large part of the head end of the mesonephros atrophies and disappears; of the remainder the anterior tubules form the efferent ducts of the testis; while the posterior tubules

are represented by the ductuli aberrantes, and by the paradidymis which is sometimes found in front of the spermatic cord above the head of the epididymis (fig. 230, C).

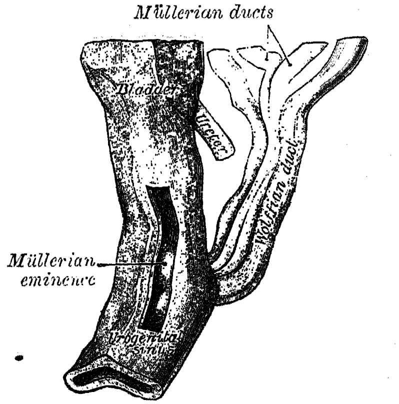
FIG. 228.—The broad ligament of an adult, showing the epoöphoron. (From Farre, after Kobelt.)



a, *a*. Epoöphoron formed from the upper part of the Wolffian body. *b*. Remains of the uppermost tubes, sometimes forming appendices. *c*. Middle set of tubes. *d*. Some lower atrophied tubes. *e*. Atrophied remains of the Wolffian duct. *f*. Terminal bulb or hydatid. *h*. Uterine tube, originally the proximal part of the Müllerian duct. *i*. Appendix attached [illegible] extremity. *l*. Ovary.

In the female the Wolffian bodies and ducts atrophy. The remains of the Wolffian tubules are represented by the epoöphoron or organ of Rosenmüller, and the paroöphoron, two small collections of rudimentary, blind tubules which are situated in the mesosalpinx (fig. 228). The lower part of the Wolffian duct disappears, while the upper part persists as the longitudinal duct of the epoöphoron or duct of Gärtner * (fig. 230, B).

FIG. 229.—The urogenital sinus of a female human embryo, eight and a half to nine weeks old. (From a model by Keibel.)



The **Müllerian ducts.**—Shortly after the formation of the Wolffian ducts a second pair of ducts is developed; these are named the *Müllerian ducts*. Each arises on the lateral aspect of the corresponding Wolffian duct as a tubular invagination of the cells lining the cœlom (fig. 226). The orifice of the invagination remains patent, and undergoes enlargement and modification to form the abdominal ostium of the uterine tube. The ducts pass backwards, and run at first lateral to the Wolffian ducts; towards the posterior end of the embryo they cross to the medial side of the Wolffian ducts, and run side by side between and dorsal to them—the four ducts forming the *genital cord* (fig. 229). The Müllerian ducts end on the *Müllerian eminence*, an epithelial elevation in the ventral part of the cloaca between the orifices of the Wolffian ducts; at a later date they open into the cloaca in this situation.

* Berry Hart (*op. cit.*) has described the Wolffian ducts as ending at the site of the future hymen in bulbous enlargements, which he has named the *Wolffian bulbs*; and states that the hymen is formed by these bulbs, 'aided by a special involution from below of the cells lining the urogenital sinus.' He further believes that 'the lower third of the vagina is due to the coalescence of the upper portion of the urogenital sinus and the lower ends of the Wolffian ducts,' and that 'the epithelial lining of the vagina is derived from the Wolffian bulbs.' He also regards the colliculus seminalis of the male urethra as being formed from the lower part of the Wolffian ducts.

A

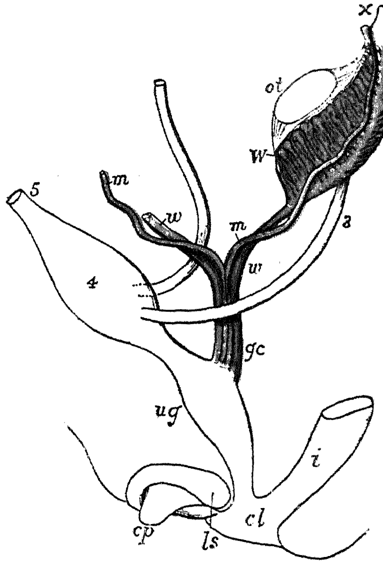
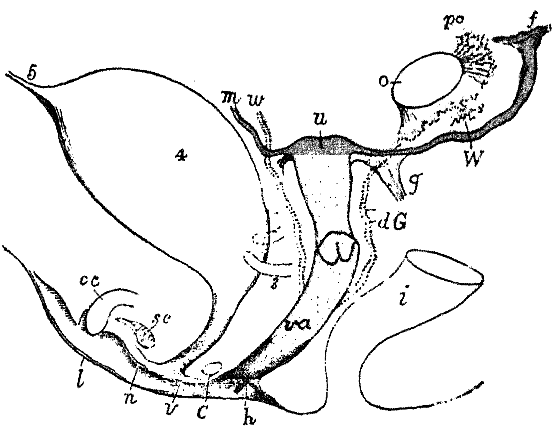


FIG. 230.—Diagrams to show the development of the male and female generative organs from a common type. (Allen Thomson.)

A.—A diagram of the primitive urogenital organs in the embryo previous to sexual distinction.

3. Ureter. 4. Urinary bladder. 5. Urachus. *cl.* Cloaca. *cp.* Elevation which becomes the clitoris (or the penis). *i.* Lower part of the intestine. *gc.* Genital cord. *ls.* Fold of integument from which the scrotum or the labia majora are formed. *m, m.* Right and left Müllerian ducts uniting and running with the Wolffian ducts in *gc*, the genital cord. *ot.* The genital ridge from which the ovary or the testis is formed. *ug.* Sinus urogenitalis. *W.* Left Wolffian body. *w, w.* Right and left Wolffian ducts.

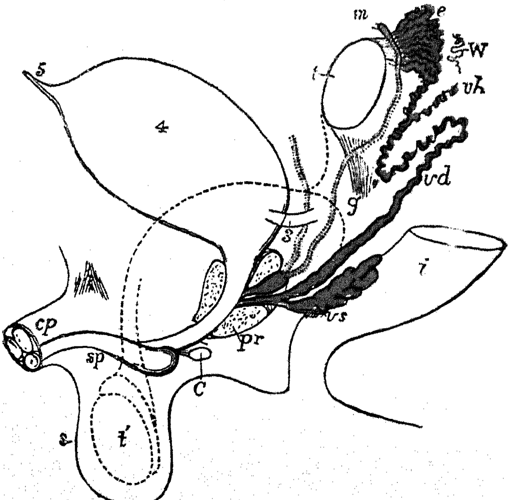
B



B.—A diagram of the female type of sexual organs.

C. Greater vestibular gland, and immediately above it the urethra. *cc.* Corpus cavernosum clitoridis. *dG.* Remains of the left Wolffian duct, persisting as the left duct of Gärtner, represented by dotted lines; that of the right side is marked *w.* *f.* Abdominal opening of the left uterine tube. *g.* Round ligament, corresponding to the gubernaculum. *h.* Situation of the hymen. *i.* Lower part of the intestine. *l.* Labium majus. *n.* Labium minus. *o.* Left ovary. *po.* Epoöphoron. *sc.* Corpus cavernosum urethræ. *u.* Uterus. *m.* Right uterine tube. *v.* Vulva. *va.* Vagina. *W.* Scattered remains of Wolffian tubes forming the paroöphoron.

C



C.—A diagram of the male type of sexual organs.

C. Bulbo-urethral gland of one side. *cp.* Corpora cavernosa penis cut short. *e.* Caput epididymis. *g.* Gubernaculum. *i.* Lower part of the intestine. *m.* Müllerian duct, the upper part of which remains as the appendix testis (hydatid of Morgagni); the lower part, represented by a dotted line descending to the prostatic utricle, constitutes the occasionally existing cornu of the utricle. *pr.* Prostate. *s.* Scrotum. *sp.* Corpus cavernosum urethræ. *t.* Testis in the place of its original formation. *t'*, together with the dotted lines above, indicates the direction in which the testis and epididymis descend from the abdomen into the scrotum. *vd.* Ductus deferens. *vh.* Ductulus aberrans. *vs.* Vesicula seminalis. *W.* Scattered remains of the Wolffian body.

In the male the Müllerian ducts atrophy, but traces of their anterior ends are represented by the appendices of the testes (hydatids of Morgagni), while their terminal fused portions form the utricle which opens into the floor of the prostatic portion of the urethra (fig. 230, C).

In the female the Müllerian ducts persist and undergo further development. The portions of the ducts which lie in the genital cord fuse to form the uterus: the parts which are proximal to this cord remain separate, and each forms the corresponding uterine tube—the abdominal ostium of which is developed from the anterior extremity of the original tubular invagination from the cœlom (fig. 230, B). The fusion of the distal parts of the Müllerian ducts begins in the third month, and the septum formed by their fused medial walls disappears from behind forwards, and thus the cavity of the uterus is produced. In some animals, and occasionally in the human subject, the septum persists, giving rise to a bicornuate uterus. About the fifth month an annular constriction marks the position of the neck of the uterus, and after the sixth month the walls of the uterus begin to thicken. The vagina is formed from two solid extensions from the ends of the Müllerian ducts; these grow at first as solid cords which push their way towards the urogenital septum. The ends fuse with one another, and by the breaking down of the central cells the cavity of the vagina results, and this cavity opens on the exterior through the urogenital septum; a portion of the septum remains to form the hymen.

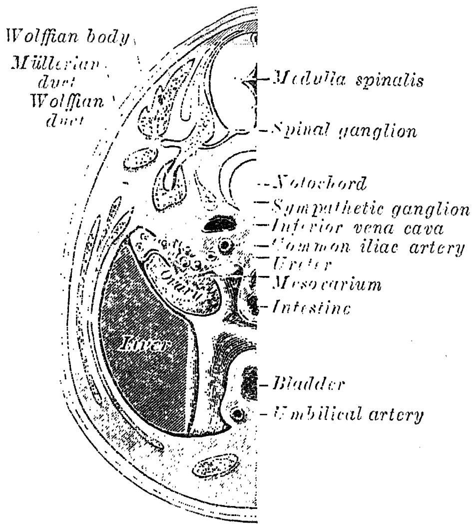


FIG. 231.—A transverse section through a human embryo, eight and a half to nine weeks old. (From a model by Keibel.)

The **genital glands**.—The first appearance of the genital gland is essentially the same in the two sexes, and consists of a thickening of the epithelial layer which lines the cœlomic cavity on the medial side of the urogenital fold (fig. 226). The thick plate of epithelium (*genital epithelium*) extends deeply, and, pushing the mesoderm before it, forms a distinct projection, termed the *genital ridge* (fig. 226). From the latter the testis in the male and the ovary in the female are developed. At first the mesonephros and genital ridge are suspended by a common mesentery, but as the embryo grows the genital ridge is gradually pinched off from the mesonephros, with which it is at first continuous, though it still remains connected to the remnant of this body by a fold of peritoneum, the *mesorchium* (*or mesovarium*) (fig. 231). The distinction of sex in the genital ridge is perceptible about the seventh week.

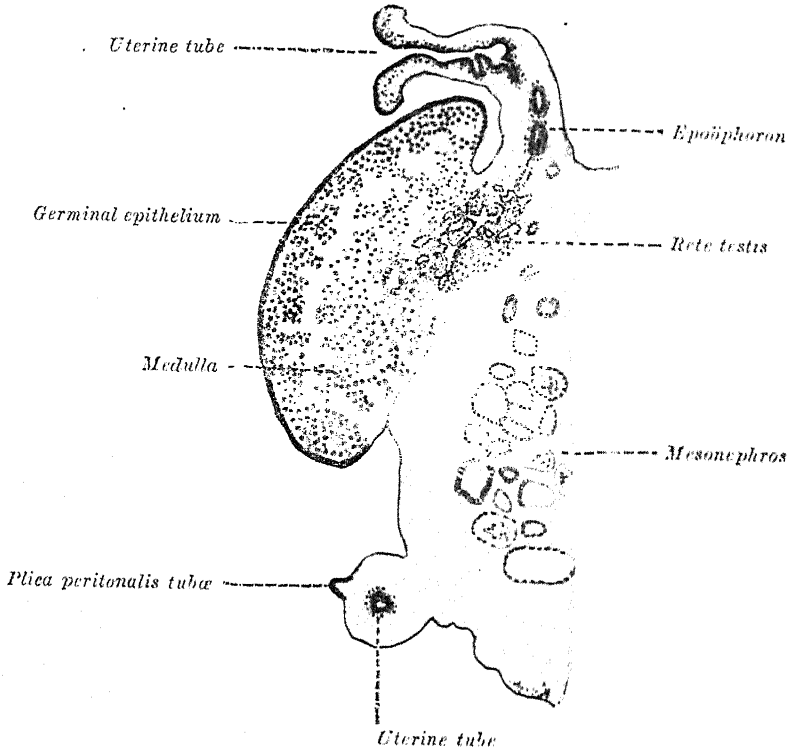
In a 10 mm. embryo the genital gland reaches from about the sixth to the twelfth thoracic segment. It subsequently extends as far as the second sacral segment, but simultaneously with this caudal extension the cranial three-fourths of the gland undergo degeneration.

The **ovary**, formed from the genital ridge, is at first a group of cells derived from the genital epithelium; later the group is differentiated into a central mass and a layer of surface epithelium (fig. 232). Between the cells of the surface epithelium a number of larger cells, the *primitive ova*, are found, and these are carried into the subjacent stroma by bud-like ingrowths (*genital cords*) of the surface epithelium (fig. 233). The surface epithelium ultimately forms the permanent epithelial covering of this organ; it loses its connexion with the central mass of cells, and a tunica albuginea develops between them. The ova are chiefly derived from the cells of the central mass; these cells are separated from one another by an irregularly arranged growth of connective tissue; each ovum assumes a covering of connective tissue (follicle) cells, and in this way the rudiments of the ovarian follicles are formed (fig. 233).

It was formerly supposed that the primitive germ-cells were derived from the cœlomic epithelium covering the genital ridge, but it has been shown that, in the lower vertebrates at least, they are probably formed during the later stages of cell-cleavage. They can be distinguished from the somatic cells by the large size of their bodies and nuclei, and by their cytoplasm which is only faintly granular and has no affinity for ordinary stains, but assumes a brownish colour when treated by osmic acid. These primitive germ-cells migrate first into the root of the mesentery and from there into the cœlomic epithelium covering the genital ridge. A considerable number apparently never reach their proper destination, since 'vagrant germ-cells are found in all sorts of places, but more particularly on the mesentery.'* Some of these may possibly find their way into the germinal ridge; some probably undergo atrophy, while others may persist and become the seat of dermoid tumours.

The **testis** is developed in much the same way as the ovary. Like the ovary, in its earliest stages it consists of a central mass of epithelial cells covered by a surface

FIG. 232.—A longitudinal section of the ovary of a cat embryo, 9·4 cm. long. Schematic. (After Coert, from Hertwig's Handbuch der Entwickelungslehre.)



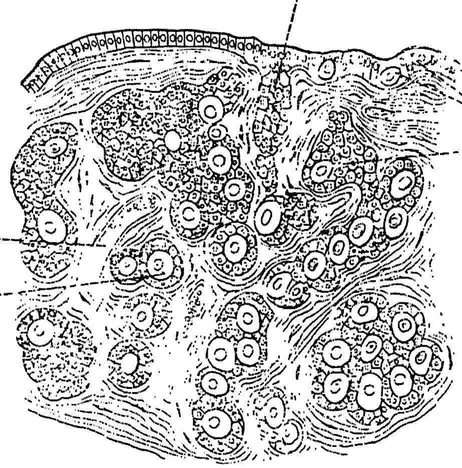
epithelium. In the central mass a series of epithelial cords (testis-cords) appear (fig. 234); simultaneously the peripheral part of the central mass is converted into a tunica albuginea which intervenes between the testis-cords and the surface epithelium and excludes the latter from any part in the formation of the tissue of the testis. The thin inner ends of the testis-cords converge towards the future hilum and there unite in a network which ultimately becomes the rete testis. From the outer parts of the testis-cords the seminiferous tubules are developed, and between them connective tissue septa extend. The tubules of the rete testis become connected with outgrowths from the Wolffian body, which, as already mentioned, form the efferent ducts of the testis.

The descent of the testes.—The testes at an early period of fœtal life, are placed in the posterior part of the abdominal cavity, and each is attached to the mesonephros by a peritoneal fold, named the *mesorchium*. From the front of the mesonephros a fold of peritoneum, termed the *inguinal fold*, grows forwards to meet and fuse with a peritoneal fold, named the *inguinal crest*, which grows backwards

* Beard, *Journal of Anatomy and Physiology*, vol. xxxviii.

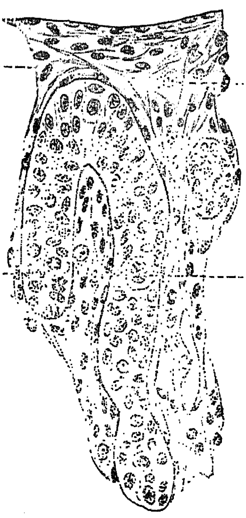
from the anterolateral abdominal wall. The testis thus acquires an indirect connexion with the anterior abdominal wall; and at the same time a portion of the peritoneal cavity lateral to these fused folds is marked off as the future saccus

FIG. 233.—A section through the ovary of a new-born child. (Waldeyer.)



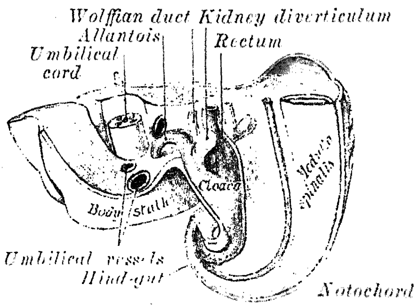
vaginalis. In the inguinal crest a peculiar structure, the *gubernaculum testis*, makes its appearance. This is at first a slender band, extending from that part of the skin which afterwards forms the scrotum, through the inguinal canal to the body and epididymis of the testis. As development advances, the peritoneum enclosing the gubernaculum forms two folds, one above the testis and the other below it. The one above the testis is the *plica vascularis*, and contains ultimately the testicular vessels. The one below, the *plica gubernatrix*, contains the lower part of the gubernaculum and ends at the abdominal inguinal ring in a tube of peritoneum, the *saccus vaginalis*, which protrudes down the inguinal canal. By the fifth month the upper part of the gubernaculum has disappeared, while the lower part has become a thick cord, and consists of a central core of unstriped muscle-fibres, and outside this of a firm layer of striped elements, connected with the abdominal wall; as the scrotum develops, the main portion of the lower end of the gubernaculum is carried, with the skin to which it is attached, to the bottom of this pouch. The saccus vaginalis projects itself downwards into the inguinal canal, and emerges at the subcutaneous inguinal ring, pushing before it a part of the Obliquus internus and the aponeurosis of the Obliquus externus, which form respectively the Cremaster muscle and the intercrural fascia. It forms a gradually elongating pouch, which eventually reaches the bottom of the scrotum, and behind this pouch the gubernaculum lies. The testis, being attached by the

FIG. 234.—A section through a genital cord of the testis of a human embryo 3·5 cm. long. (Felix and Bühler.)



gubernaculum to the bottom of the scrotum, passes first into the inguinal canal and eventually into the scrotum, invaginating the saccus vaginalis from behind. It seems certain also that the gubernacular cord becomes shortened as development proceeds, and this assists in causing the testis to reach the bottom of the scrotum. By the end of the eighth month the testis has reached the scrotum, and the upper part of the saccus vaginalis is converted into a narrow canal which is obliterated a short time after birth, and this obliteration extends gradually downwards to within a short distance of the testis. The lower part of the saccus vaginalis is thus entirely cut off from the general peritoneal cavity and constitutes the parietal portion of the *tunica vaginalis*.

Fig. 235.—The tail-end of a human embryo, twenty-five to twenty-nine days old. (From a model by Keibel.)

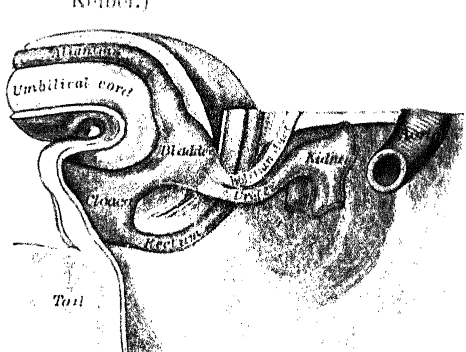


Descent of the ovaries.—In the female there is also a gubernaculum, which effects a considerable change in the position of the ovary, though not so extensive as that of the testis. The gubernaculum in the female lies in contact with the fundus of the uterus and contracts adhesions to this organ. The part of the gubernaculum between the ovary and the uterus becomes the ligament of the ovary, the part between the uterus and the labium majus the round ligament of the uterus; a pouch of peritoneum analogous to the saccus vaginalis in the male accompanies it along the inguinal canal; it is called the *canal of Nuck*.

Applied Anatomy.—Sometimes the testes are retained within the abdomen or inguinal canal, constituting what is known as cryptorchismus. In the female, in rare cases, the gubernaculum fails to contract adhesions to the uterus, and then the ovary descends through the inguinal canal into the labium majus, and its position resembles that of the testis.

The **metanephros and the permanent kidney.**—The rudiments of the permanent kidneys make their appearance about the end of the first or the beginning of the second month. Each kidney has a twofold origin, part arising from the metanephros, and part as a diverticulum from the hind-end of the Wolffian duct close to where the latter opens into the cloaca (figs. 235, 236). The metanephros arises in the intermediate cell-mass, caudal to the mesonephros which it resembles in structure. The diverticulum from the Wolffian duct grows dorsalwards and cranialwards along the posterior abdominal wall, where its blind extremity expands and subsequently divides into several buds, which form the rudiments of the pelvis and calyces of the kidney; the collecting tubules are developed by continued growth and subdivision of the buds. The proximal portion of the diverticulum becomes the ureter. The secretory tubules are developed from the metanephros, which is moulded over the growing end of the diverticulum from the Wolffian duct. The tubules of the metanephros, unlike those of the pronephros and mesonephros, do not open into the Wolffian duct. One end of each tubule expands to form a glomerulus, while the remainder rapidly elongates to form the convoluted tubule, the loop of Henle, and the junctional tubule; the last joins and establishes communication with one of the collecting tubules which are derived from the ultimate ramifications of the diverticulum from the Wolffian duct. The

Fig. 236.—The tail-end of a human embryo, thirty-two to thirty-three days old. (From a model by Keibel.)



mesoderm around the tubules is condensed to form the connective tissue of the kidney. The ureters open at first into the hind-end of the Wolffian ducts; but after the sixth week they open independently into the part of the cloaca which ultimately becomes the bladder (figs. 237, 238).

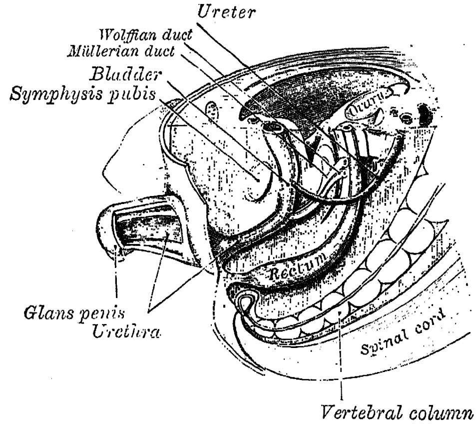
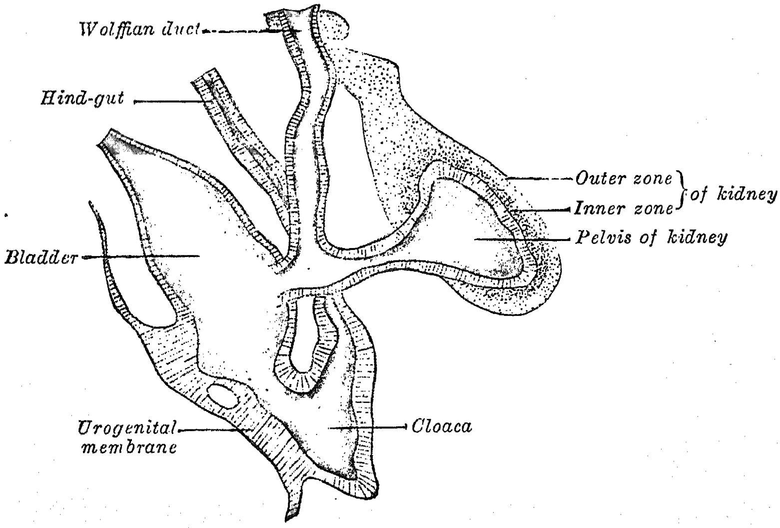


FIG. 237.—The tail-end of a human embryo, eight and a half to nine weeks old. (From a model by Keibel.)

The secretory tubules of the kidney are arranged into pyramidal masses or lobules, the bases of which are at the surface of the kidney, while their apices constitute the renal papillæ. The lobulated condition of the kidneys exists for some time after birth and traces of it may be found in the adult. The kidneys of the ox and many other animals remain lobulated throughout life.

The **urinary bladder** is formed partly from the entodermal cloaca and partly from the ends of the Wolffian ducts. After the separation of the rectum from the dorsal part of the cloaca (p. 142), the ventral part of the latter becomes subdivided into three portions: (1) a dorsal *vesico-urethral portion*, continuous with the allantois—into this portion the Wolffian ducts open; (2) an intermediate narrow channel, the *pelvic portion*; and (3) a ventral broad *phallic portion*, closed externally by the urogenital membrane (fig. 238). The second and third parts together constitute the *urogenital sinus*. The vesico-urethral portion incorporates the hind-ends of the Wolffian ducts and the associated ends of the renal diverticula, and these give rise to the trigone of the bladder and part of the prostatic urethra. The remainder of the vesico-urethral portion forms the body of the bladder and part of the prostatic urethra; its apex is prolonged to the umbilicus as a narrow canal, which later is obliterated and becomes the medial umbilical ligament (urachus).

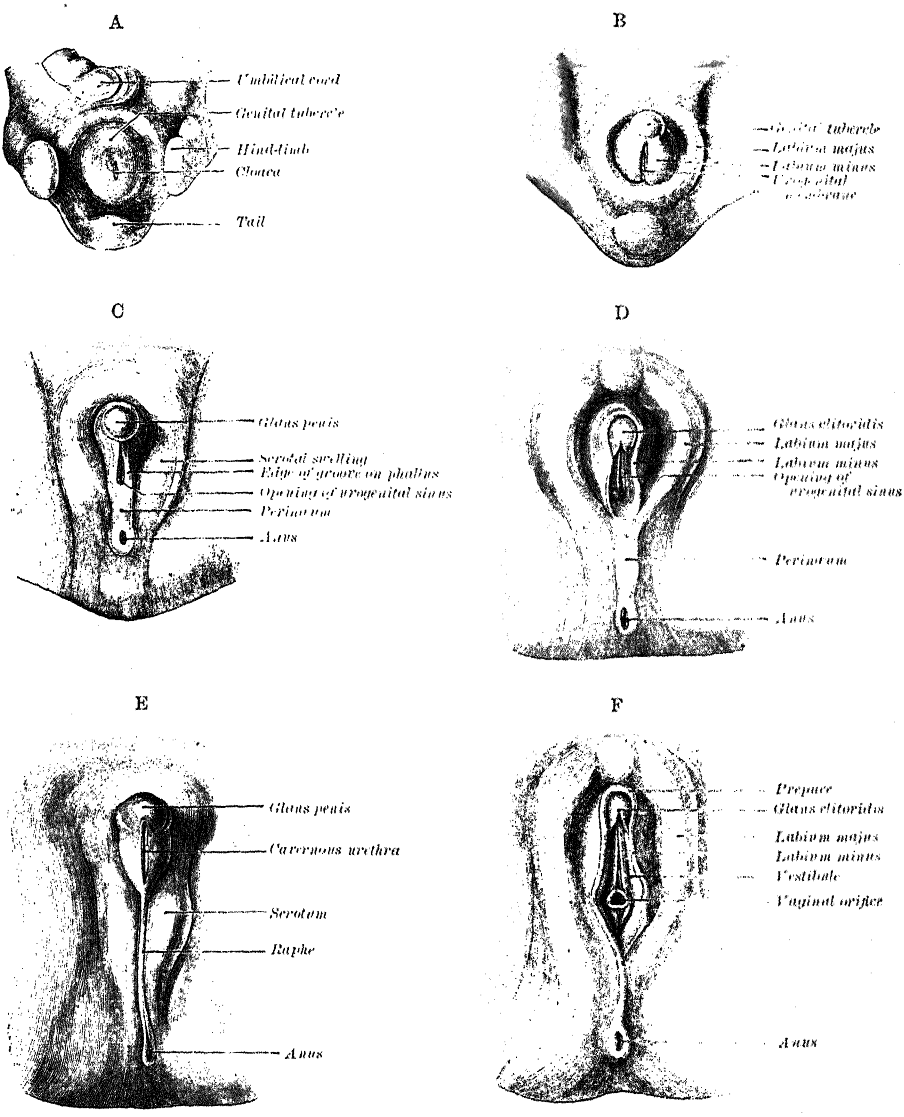
FIG. 238.—The primitive kidney and the bladder, from a reconstruction. (After Schreiner.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



The **prostate** originally consists of two separate portions, each of which arises as a series of buds from the epithelial lining of the urogenital sinus and vesico-urethral part of the cloaca, between the third and fourth months. These buds

become tubular, and form the glandular substance of the two lobes which ultimately meet and fuse behind the urethra and also extend on to its ventral aspect. The isthmus or middle lobe is formed as an extension of the lateral lobes between the common ejaculatory ducts and the bladder. In the female the urethral glands which open into the para-urethral ducts (Skene's ducts) are believed to be the homologues of the prostatic glands.

Fig. 239.—Stages in the development of the external sexual organs in the male and female. (From the Ecker-Ziegler models.)



The *bulbo-urethral glands of Cowper* in the male, and *greater vestibular glands of Bartholin* in the female, also arise as diverticula from the epithelial lining of the urogenital sinus.

The **external organs of generation** (fig. 239).—As already stated (p. 142), the cloacal membrane, composed of ectoderm and entoderm, originally reaches from the umbilicus to the tail. The mesoderm extends to the midventral line for some distance behind the umbilicus, and forms the lower part of the abdominal wall; it ends below in a prominent swelling, the *cloacal tubercle*. Behind this tubercle the urogenital part of the cloacal membrane separates the ingrowing sheets of mesoderm.

The first rudiment of the penis (or clitoris) is a structure termed the *phallus*; it is derived from the phallic portion of the cloaca which has extended on to the end and sides of the under surface of the cloacal tubercle. The terminal part of the phallus, representing the future glans penis, becomes solid; the remainder, which is hollow, is converted into a longitudinal groove by the absorption of the urogenital membrane.

In the female a deep groove forms around the phallus and separates it from the rest of the cloacal tubercle, which is now termed the *genital tubercle*. The sides of the genital tubercle grow backwards as the *genital swellings*, which ultimately form the labia majora; the tubercle itself becomes the mons pubis. The labia minora arise by the continued growth of the lips of the groove on the under surface of the phallus; the remainder of the phallus forms the clitoris.

In the male the early stages are similar, but the pelvic portion of the cloaca undergoes much greater development, pushing before it the phallic portion. The genital swellings extend round between the pelvic portion and the anus, and form a scrotal area; during the changes associated with the descent of the testes this area is drawn out to form the scrotal sacs. The penis is developed from the phallus. As in the female, the urogenital membrane undergoes absorption, forming a channel on the under surface of the phallus; this channel extends only as far forwards as the corona glandis.

The corpora cavernosa of the penis (or clitoris) and of the urethra arise from the mesodermal tissue in the phallus; they are at first dense structures, but later vascular spaces appear in them, and they gradually become cavernous.

The *prepuce* is formed by the growth of a solid plate of ectoderm into the superficial part of the phallus; on coronal section this plate presents the shape of a horseshoe. By the breaking down of its more centrally situated cells the plate is split into two lamellæ, and a cutaneous fold, the prepuce, is liberated which forms a hood over the glans. 'Adherent prepuce is not an adhesion really, but a hindered central desquamation' (Berry Hart, *op. cit.*).

The **urethra**.—As described above, in both sexes the phallic portion of the cloaca extends on to the under surface of the cloacal tubercle as far forwards as the apex. At the apex the walls of the phallic portion come together and fuse, the lumen is obliterated, and a solid plate, the *urethral plate*, is formed. The remainder of the phallic portion is for a time tubular, and then, by the absorption of the urogenital membrane, it establishes a communication with the exterior; this opening is the *primitive urogenital ostium*, and extends forwards to the corona glandis.

In the female this condition is largely retained; the portion of the groove on the clitoris broadens out while the body of the latter enlarges, and thus the adult urethral opening is situated behind the base of the clitoris.

In the male, by the greater growth of the pelvic portion of the cloaca a longer urethra is formed, and the primitive ostium is carried forwards with the phallus, but it still ends at the corona glandis. Later the groove closes from behind forwards. Meanwhile the urethral plate of the glans breaks down centrally to form a median groove continuous with the primitive ostium. This groove also closes from behind forwards, so that the external urethral opening is shifted forwards to the end of the glans penis.

THE FORM OF THE EMBRYO AT DIFFERENT STAGES OF ITS GROWTH.

During the first week the ovum is in the uterine tube. Having been fertilised in the upper part of the tube, it passes slowly along the tube—undergoing segmentation meanwhile—and ultimately reaches the uterus. Peters * described a specimen, the age of which he reckoned as from three to four days, but which was probably about fourteen days.† It was embedded in the decidua on the posterior wall of the uterus and enveloped by a decidua capsularis, the central part of which, however, consisted merely of a layer of fibrin. The ovum was in the form of a sac, the outer wall of which consisted of a layer of trophoblast; inside this was a thin layer of mesoderm composed of round, oval, and spindle-shaped cells. Numerous villous processes—some consisting of trophoblast only, others possessing a core of mesoderm—projected from the surface of the ovum into the surrounding decidua. Inside this sac the rudiment of the embryo was found in the form of a patch of ectoderm, covered by a small but completely closed amnion. It possessed a minute archenteron

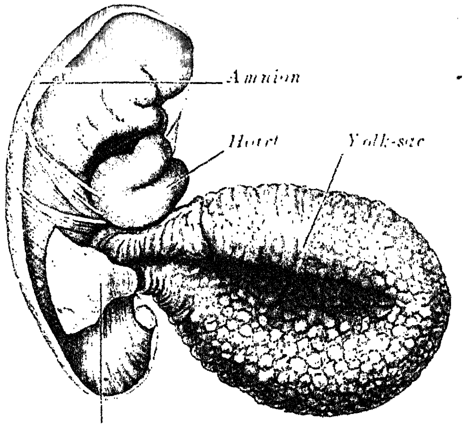
* Hubert Peters, *Die Einbettung des menschlichen Eies*, 1899.

† Bryce and Teacher (*Early Development and Imbedding of the Human Ovum*, 1908) describe an ovum, the age of which they estimate at 13 to 14 days; they are of opinion that the age of Peters' ovum has been greatly understated, and should be reckoned as from 13½ to 14½ days.

and was surrounded by mesoderm, which was connected by a band to the mesoderm lining the trophoblast (fig. 94).

By the third week the cephalic and caudal folds of the embryo are evident; the neural groove is partly closed, and six or seven pairs of primitive segments are present (fig. 83).

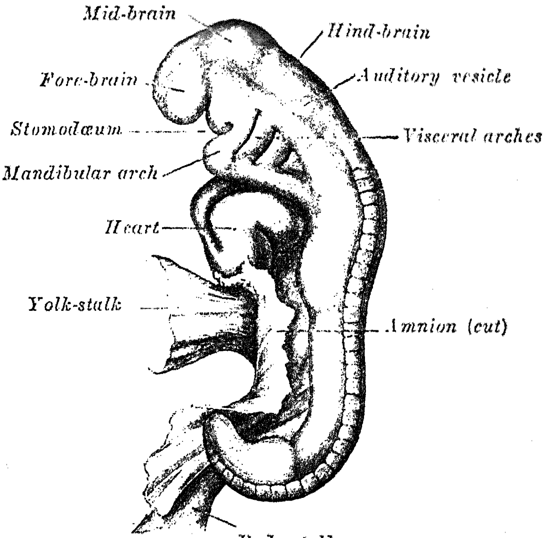
Fig. 240.—A human embryo, 2·6 mm. long. (His.)



In the fourth week the embryo is about 2·5 mm. long, and thirty pairs of primitive segments are differentiated. The brain-vesicles and the rudiment of the auditory vesicle are visible (figs. 240, 241).

In the fifth week the embryo is markedly curved on itself; the stomodæum and the branchial grooves are developed; the lens-rudiment is separated from the ectoderm and forms a closed vesicle; the rudiments of the limb-buds and of the Wolffian bodies are visible. The crown-rump length of the embryo—i.e. the length from the vertex of the head to the lowest part of the breech—is about 5 mm.

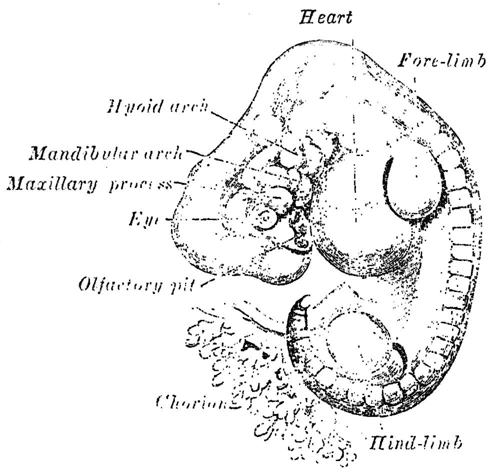
Fig. 241.—A human embryo, 4·2 mm. long. (His.)



By the sixth week the third and fourth branchial arches have receded from the surface, and form the floor of the sinus cervicalis which is covered in front by the hyoid arch. The medial and lateral nasal processes are separated by the olfactory pits; the globular processes are approaching one another; the maxillary processes are growing forward to fuse with the lateral nasal and globular processes. The three segments of each limb-bud can be recognised —the development of the fore-limb being always in advance of that of the hind-limb. Towards the end of this month the rudiments of the fingers and toes are evident, and the crown-rump length is about 11 mm.

In the seventh and eighth weeks the flexure of the head is gradually reduced and the neck is somewhat lengthened. The upper lip is completed and the nostrils are directed forwards; the palate is not completely developed. The eyelids are present in the shape of folds above and below the eye, and the different parts of the auricula are distinguishable. By the end of the eighth week the crown-rump length of the fœtus is about 25 mm.

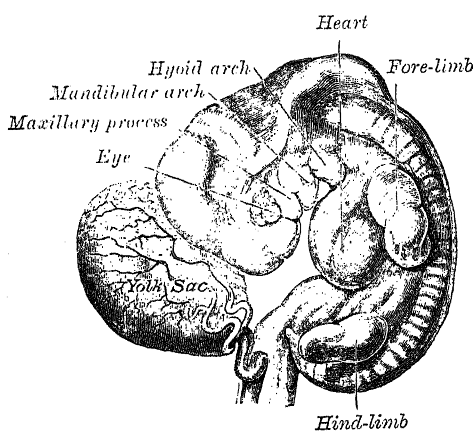
FIG. 242.—A human embryo, about 10 mm. long. (His.)



In the third month the head is extended and the neck is lengthened. The eyelids meet and fuse, remaining closed until the end of the sixth month. The limbs are well developed and nails appear on the digits. The external generative organs are so far differentiated that it is possible to distinguish the sex. By the end of this month the crown-rump length of the fœtus is about 10 cm.

In the fourth month the loop of gut which projected into the umbilical cord is withdrawn within the fœtus. The hairs begin to make their appearance. By the end of the fourth month the crown-rump length of the fœtus is about 14 cm., and the total length—i.e. including the legs—about 22 cm.

FIG. 243.—A human embryo, about 11 mm. long. (His.)



During the fifth month the first movements of the fœtus are usually observed. The eruption of hair on the head commences, and the vernix caseosa begins to be deposited. By the end of this month the total length of the fœtus is nearly 30 cm.

In the sixth month the body is covered by fine hairs (*lanugo*) and the deposit of vernix caseosa is considerable. The papillæ of the skin are developed and the free borders of the nails project from the corium of the dermis. From vertex to heels, the total length of the fœtus at the end of this month is about 33 cm. The weight is about 1 kilogram.

In the seventh month the pupillary membrane atrophies and the eyelids are open. The testis descends with the vaginal sac of the peritoneum. From vertex to heels the total length at the end of the seventh month is about 40 cm. The weight is about 1·5 kilograms.

During the eighth month the skin is entirely coated with vernix caseosa, and the lanugo begins to disappear. Subcutaneous fat has been developed to a considerable extent, and the fœtus presents a plump appearance. The total length, *i.e.* from head to heels, at the end of the eighth month is about 45 cm., and the weight varies between 2 and 2·5 kilograms.

FIG. 244.—A human embryo, about 15·5 mm. long. (His.)

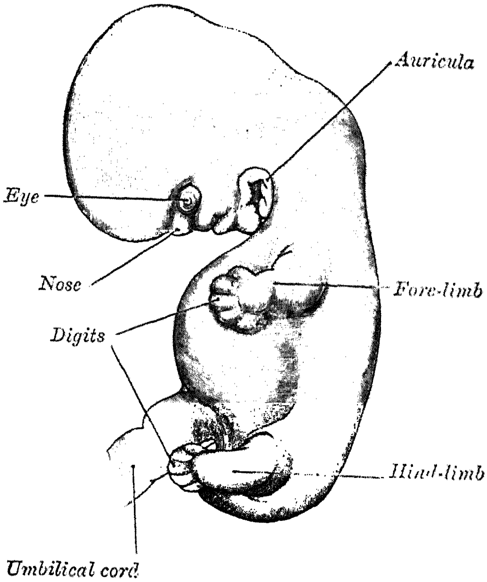
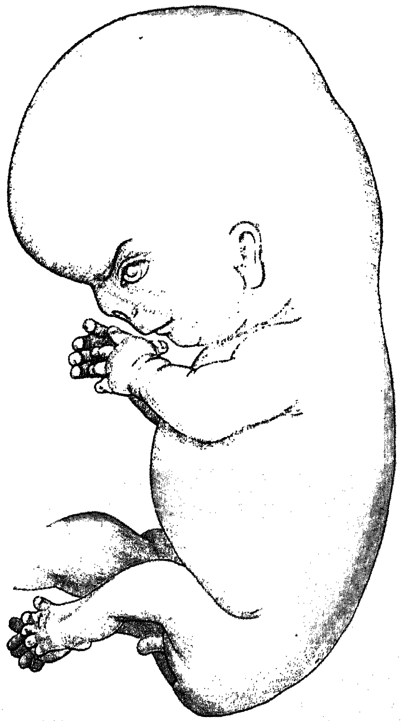


FIG. 245.—A human embryo, about 23 mm. long. (His.)



At the end of the ninth month the lanugo has largely disappeared from the trunk. The umbilicus is almost in the middle of the body and the testes are in the scrotum. The fœtus weighs from 3 to 3·5 kilograms, and measures from head to heels about 50 cm.

OSTEOLOGY

THE general framework of the body is built up mainly of a series of bones, supplemented in certain regions by pieces of cartilage; this bony and cartilaginous framework constitutes the *skeleton.*

In comparative anatomy the term skeleton has a wider application, since in some of the lower animals hard, protecting and supporting structures are developed in association with the integumentary system. In such animals the skeleton consists of an internal or deep skeleton, the *endoskeleton,* and an external or superficial, the *exoskeleton.* In the human subject the oxeskeleton is very rudimentary, its only important representatives being the nails and the enamel of the teeth, and therefore, in human anatomy, the term skeleton is confined to the endoskeleton; this is divisible into an *axial* part, which includes the bones of the head and trunk, and an *appendicular* part, which comprises those of the extremities or limbs. The minute structure and the physical properties of bone are described on pages 17 to 25.

In the skeleton of the adult there are 206 bones, grouped as follows:

Axial Skeleton	Vertebral column	26	
	Skull	22	
	Hyoid bone	1	
	Ribs and sternum	25	
		—	74
Appendicular Skeleton	Upper extremities	64	
	Lower extremities	62	
		—	126
	Auditory ossicles		6
	Total		206

Bones are divisible into four classes: *long, short, flat,* and *irregular.*

The **long bones** are found in the limbs, where they form levers; each consists of a body or shaft and two ends. The *body* or *shaft* is tubular, with a central cavity termed the *medullary cavity*; the wall consists of dense, compact substance of considerable thickness in the middle part of the body of the bone, but becoming thinner towards the ends; projecting into the medullary cavity is some spongy substance, scanty in the middle of the body of the bone, but plentiful towards the ends. The *ends* are usually expanded, for purposes of articulation and muscular attachment; they consist of spongy substance covered by thin compact bone, and are usually developed from one or more secondary or *epiphysial* centres of ossification. The medullary cavity and the spaces in the spongy substance are filled with marrow (*medulla ossium*).

The **short bones.**—Where a part of the skeleton is intended for strength and compactness combined with limited movement, it is constructed of a number of short bones, as in the *carpus* and *tarsus.* These bones consist of spongy substance surrounded by a thin crust of compact bone.

The **flat bones.**—Where the principal requirement of the skeleton is to protect delicate structures or provide broad surfaces for muscular attachment, the bones are expanded into plates, as in the skull and the scapulæ, and are composed of two thin layers of compact bone separated by a variable quantity

of spongy substance. In the cranial bones, the layers of compact bone are familiarly known as the *tables* of the skull; the outer table is thick and tough, the inner thin, dense, and brittle. The intervening spongy substance is called the *diploë*, and this, in certain regions of the skull, undergoes absorption, and spaces filled with air (*air-sinuses*) are left between the two tables of the skull.

The **irregular bones**, from their peculiar form, cannot be grouped under the preceding heads. They consist of spongy substance enclosed within a thin layer of compact bone.

Surface of bones.—On the surfaces of the bones there are eminences and depressions, either articular or non-articular. Examples of *articular eminences* are the heads of the humerus and femur; and of *articular depressions* the glenoid cavity of the scapula, and the acetabulum of the hip-bone. *Non-articular eminences* are designated according to their form. Thus, a broad, rough, uneven elevation is called a *tuberosity*, *trochanter*, *protuberance*, or *process*; a small, rough prominence, a *tubercle*; a sharp, slender, pointed eminence, a *spine*; a narrow, rough elevation of some length, a *ridge*, *crest*, or *line*. *Non-articular depressions* are also of variable form, and are described as *fossæ*, *pits*, *depressions*, *grooves*, *furrows*, *fissures*, *notches*, *&c.*

THE VERTEBRAL COLUMN (COLUMNA VERTEBRALIS)

The **vertebral column** (fig. 277) is a flexuous and flexible column, formed of a series of bones called *vertebræ*, which are united to one another by intervertebral fibrocartilages. The bones are thirty-three in number, and are grouped under the names *cervical*, *thoracic*, *lumbar*, *sacral*, and *coccygeal*, according to the regions they occupy; there are seven cervical vertebræ, twelve thoracic, five lumbar, five sacral, and four coccygeal.

The cervical, thoracic, and lumbar vertebræ are separate bones throughout life, and are therefore known as *movable* vertebræ; the sacral and coccygeal vertebræ, on the other hand, are termed *fixed* vertebræ, because they are united in the adult to form two bones, viz. the *sacrum* and *coccyx*, formed respectively by the fused sacral and coccygeal vertebræ.

The General Characteristics of a Vertebra

With the exception of the first and second cervical, the movable vertebræ have certain common characteristics which are best studied by examining one from the middle of the thoracic region.

A typical **vertebra** (fig. 246) consists of two principal parts, an anterior, the *body*, and a posterior, the *vertebral arch*; these enclose a foramen, the *vertebral foramen*.

In the articulated vertebral column the bodies form a pillar for the support of the head and trunk, and the vertebral foramina constitute a canal in which the medulla spinalis or spinal cord is lodged and protected. Between every pair of vertebræ are two *intervertebral foramina*, one on either side, for the transmission of the spinal nerves and vessels.

The **body** of a vertebra is more or less cylindrical in shape; its upper and lower surfaces are flattened and rough, and give attachment to the intervertebral fibrocartilages, and each presents a rim around its circumference. In front, it is convex from side to side and concave from above downwards; behind, it is slightly concave from side to side and flat from above downwards. On its anterior surface are a few small apertures for the passage of nutrient vessels; on its posterior surface is a large, irregular aperture (occasionally more than one) for the exit of the basivertebral veins from the body of the vertebra.

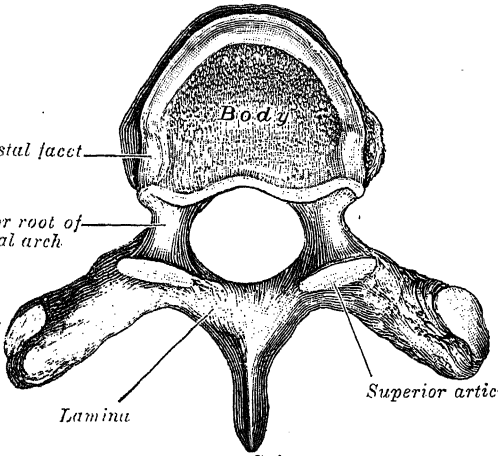
The **vertebral arch** consists of a pair of *pedicles* or *roots* and a pair of *laminæ*; it supports seven *processes*, viz. four *articular*, two *transverse* and one *spinous*.

The *pedicles* or *roots of the vertebral arches*, are two short, thick processes, which project backwards from the body, at the junctions of its lateral and

posterior surfaces. The concavities above and below the pedicles are named the *vertebral notches*; and when the vertebræ are articulated with one another, the notches of contiguous pairs form the *intervertebral foramina*, already referred to.

The *laminæ* are two broad plates directed backwards and medialwards from the pedicles. They fuse in the middle line posteriorly, and so complete

FIG. 246.—A typical thoracic vertebra. Superior aspect.



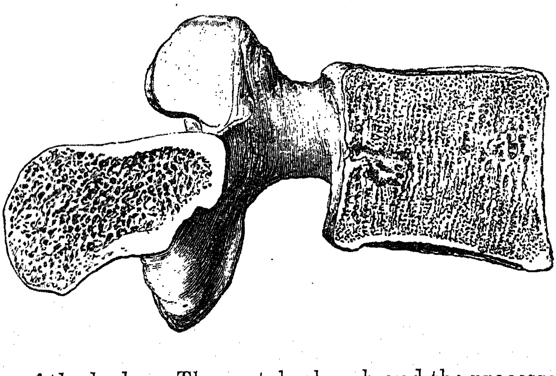
the posterior boundary of the vertebral foramen. Their upper borders and the lower parts of their anterior surfaces are rough for the attachment of the ligamenta flava.

The *spinous process* is directed backwards and downwards from the junction of the laminæ, and serves for the attachment of muscles and ligaments.

The *articular processes*, two superior and two inferior, spring from the junctions of the pedicles and laminæ. The superior processes project upwards, and their articular surfaces are directed more or less backwards; the inferior project downwards, and their articular surfaces look more or less forwards.

The *transverse processes* project lateralwards from the junctions of the pedicles and laminæ; they serve for the attachment of muscles and ligaments.

FIG. 247.—A sagittal section through a lumbar vertebra.



Structure of a vertebra (fig. 247).—The body of a vertebra is composed of spongy substance covered by a thin coating of compact bone; the latter is perforated by numerous orifices for the passage of vessels; the interior of the body is traversed by one or two large canals, for the reception of veins, which converge towards the large aperture on the posterior surface of the body. The vertebral arch and the processe projecting from it have thick coverings of compact substance.

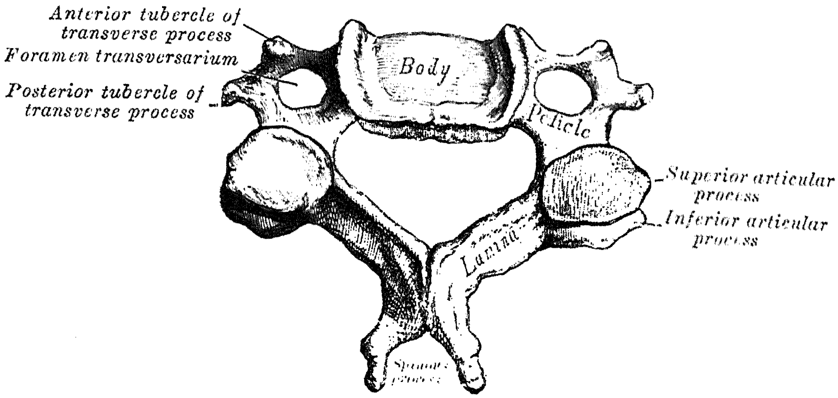
THE CERVICAL VERTEBRÆ (VERTEBRÆ CERVICALES)

The **cervical vertebræ** (figs. 248, 249), seven in number, are the smalles of the movable vertebræ, and can be readily distinguished from the thoracic o lumbar vertebræ by the presence of a foramen in each transverse process.

The first, second, and seventh cervical vertebræ present exceptional features, but the following characteristics are common to the remaining four.

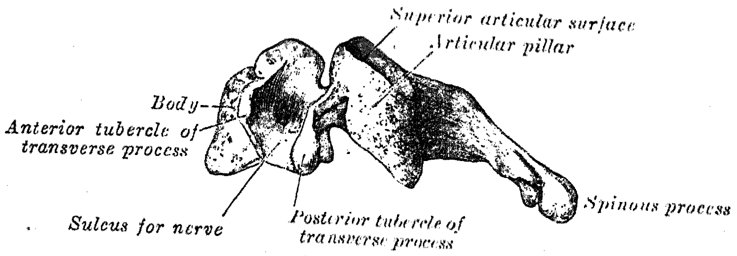
The *body* is small, and broader from side to side than from before backwards. The anterior and posterior surfaces are flattened and of equal depth, but the anterior surface is placed on a lower level than the posterior, and its inferior border is prolonged downwards, so as to overlap the upper and front part of the succeeding vertebra. The superior surface is concave transversely, and has an

FIG. 248.—A typical cervical vertebra. Superior aspect.



upwardly projecting lip on either side; the inferior surface is saddle-shaped, being concave from before backwards, convex from side to side, and presents laterally shallow concavities which receive the projecting lips of the subjacent vertebra. The *pedicles* are directed lateralwards and backwards; they are attached to the body midway between its upper and lower borders, and therefore the superior and inferior vertebral notches are of equal depth; the superior notch is, however, the narrower. The *laminæ* are narrow, and are thinner above than below; the *vertebral foramen* is large, and of triangular form. The *spinous process* is short and bifid, and its terminal tubercles are often of unequal size. The *superior and inferior articular processes* of either side are fused to form an articular pillar, which projects lateralwards from the junction of the pedicle and lamina. The articular facets are flat and of an oval form; the superior

FIG. 249.—A typical cervical vertebra. Left lateral aspect.



facets look backwards, upwards, and slightly medialwards; the inferior forwards, downwards, and slightly lateralwards. In the third and fourth vertebræ the lateral surfaces of the articular pillars are grooved for the accommodation of the medial branches of the posterior divisions of the corresponding cervical nerves.* The *transverse processes* are each pierced by the *foramen transversarium*, which, in the upper six vertebræ, gives passage to the vertebral artery and vein and a plexus of sympathetic nerves. Each

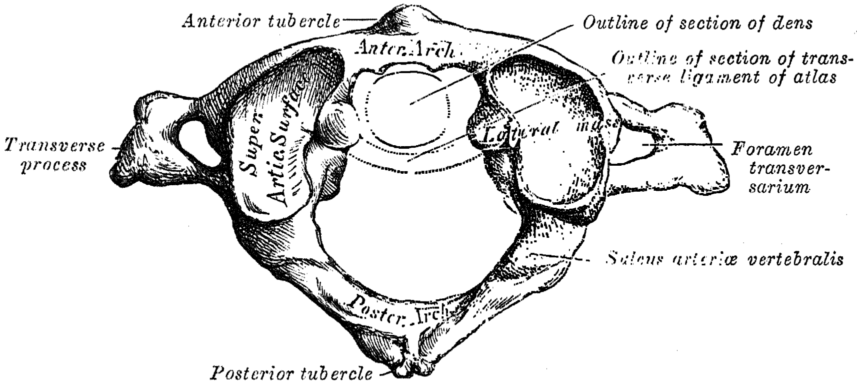
* F. Wood Jones, *Journal of Anatomy and Physiology*, vol. xlvi., 1911.

process consists of an anterior and a posterior part. The anterior portion is the homologue of the rib in the thoracic region, and is therefore named the *costal process*; it arises from the side of the body, is directed lateralwards in front of the foramen, and ends in a tubercle, the *tuberculum anterius*. The posterior part, the true transverse process, springs from the vertebral arch behind the foramen transversarium, and is directed forwards and lateralwards; it ends in a flattened vertical tubercle, the *tuberculum posterius*. Lateral to the foramen transversarium the anterior and posterior tubercles are united by a curved bar of bone, the groove or sulcus on the upper surface of which accommodates the anterior division of the corresponding spinal nerve. This sulcus is deeper, wider, and more downwardly directed in the fifth and sixth than in the third and fourth vertebræ.*

Chassaignac pointed out that the common carotid artery can be compressed against the anterior tubercle of the transverse process of the sixth cervical vertebra; this tubercle therefore is named the *tuberculum caroticum* or *Chassaignac's tubercle*. It also constitutes an important guide to the vertebral artery.

The **first cervical vertebra** (fig. 250) is named the **atlas** because it supports the globe of the head. Its chief peculiarity is that it has no body, and

FIG. 250.—The first cervical vertebra, or atlas. Superior aspect.



this is due to the fact that the body of the atlas has fused with that of the second cervical vertebra. It has no spinous process but is ring-like, and consists of an anterior and a posterior arch and two lateral masses. The *anterior arch* forms about one-fifth of the ring: its front surface is convex, and at its centre is the *anterior tubercle* for the attachment of parts of the Longus colli muscles; posteriorly it is concave, and marked by a smooth, oval or circular facet (fovea dentis), for articulation with the anterior surface of the dens or odontoid process of the epistropheus or axis. The upper and lower borders respectively give attachment to the anterior atlanto-occipital membrane and the anterior atlanto-epistropheal ligament; the former connects the atlas with the occipital bone, the latter the atlas with the epistropheus. The *posterior arch* forms about two-fifths of the ring: at the centre of its posterior surface is the *posterior tubercle*, which is the rudiment of a spinous process and gives origin to the Recti capitis posteriores minores. The small size of this process prevents it from interfering with the movements between the atlas and the skull. The upper edge of the central part of the posterior arch is rounded and affords attachment to the posterior atlanto-occipital membrane, while immediately behind the superior articular process of each lateral mass is a groove, the *sulcus arteriæ vertebralis*, sometimes converted into a foramen by a bony spiculum which arches backwards from the posterior end of the superior articular process. This sulcus lodges

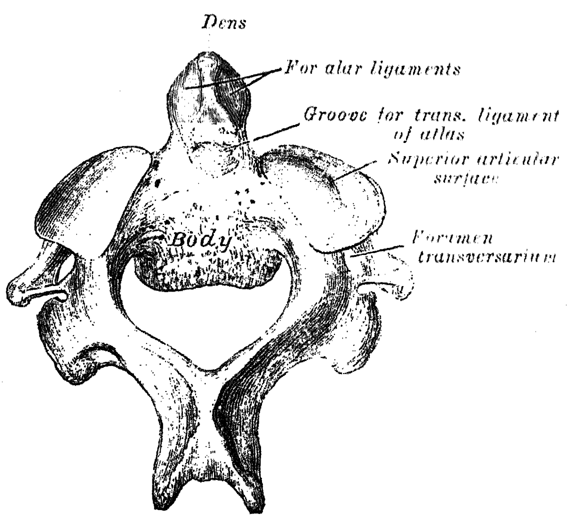
* The *costal element* of a cervical vertebra not only includes the portion which springs from the side of the body, but the anterior and posterior tubercles and the bar of bone which connects these tubercles (fig. 108).

the vertebral artery which, after ascending through the foramen in the transverse process of the atlas, winds round the lateral mass in a direction backwards and medialwards; it also lodges the suboccipital or first spinal nerve. On the under surface of the posterior arch, behind the inferior articular facets, are the two shallow vertebral notches. The lower border of the posterior arch gives attachment to the posterior atlanto-epistropheal ligament.

The *lateral masses* support the weight of the head; each contributes about one-fifth of the ring, and carries two articular facets, a superior and an inferior. The superior articular facets are large, oval, and concave; they approach each other in front, but diverge behind; they are directed upwards, medialwards, and a little backwards, and form cups for the reception of the condyles of the occipital bone, and are admirably adapted to the nodding movements of the head; occasionally they are constricted near their centres. Just below the medial margin of each superior facet is a small tubercle, for the attachment of the transverse ligament of the atlas; this ligament divides the ring of the atlas into two unequal parts—the anterior, smaller part receiving the dens or odontoid process of the epistropheus, the posterior transmitting the medulla spinalis and its membranes. The inferior articular facets, nearly circular in form, are flattened or slightly concave; they are directed downwards and medialwards, and articulate with the superior facets of the epistropheus. The *transverse processes* are long and project lateralwards and downwards from the lateral masses; the anterior and posterior tubercles of each process are fused into one mass. The foramen transversarium is large and is directed upwards and backwards.

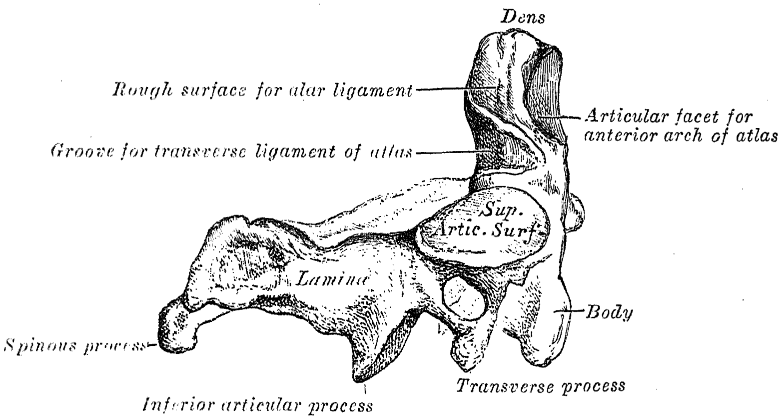
The **second cervical vertebra** or **epistropheus** (axis) (figs. 251, 252) forms the pivot upon which the atlas, carrying the head, rotates. The chief characteristic of this bone is the strong tooth-like process, the *dens*, which projects perpendicularly from the upper surface of the body. The *body* is deeper in front than behind. On its anterior surface is a median ridge, separating two depressions for the attachment of portions of the Longus colli muscles. Its inferior surface is concave from before backwards and convex from side to side. The *dens* (odontoid process), conical in shape, is about 1·5 cm. long, and exhibits a slight constriction, or neck, where it joins the body. On its anterior surface is an oval or nearly circular facet for articulation with that on the posterior surface of the anterior arch of the atlas. On the back of the neck, and frequently extending on to its lateral surfaces, is a shallow groove for the transverse ligament of the atlas, which retains the dens in position. The apex is pointed, and gives attachment to the ligamentum apicis dentis; below the apex, the process is somewhat enlarged and presents on either side a rough impression for the attachment of the alar ligaments which connect the dens to the occipital bone. The internal structure of the dens is more compact than that of the body. The *pedicles* are broad and strong, especially in front, where they fuse with the sides of the body and the base of the dens. They are covered above by the superior articular surfaces. The *laminæ* are thick and strong, and the *vertebral foramen* is large, but smaller than that of the atlas. The *transverse processes* are very small; each ends in a single tubercle and is

FIG. 251.—The second cervical vertebra, or epistropheus. Posterosuperior aspect.



perforated by the foramen transversarium which is directed upwards and lateralwards. The *superior articular surfaces* are circular, slightly convex, directed upwards and a little lateralwards, and are supported on the body, pedicles, and transverse processes ; the *inferior* have the same direction as those of the typical cervical vertebræ. The *superior vertebral notches* are very shallow, and lie

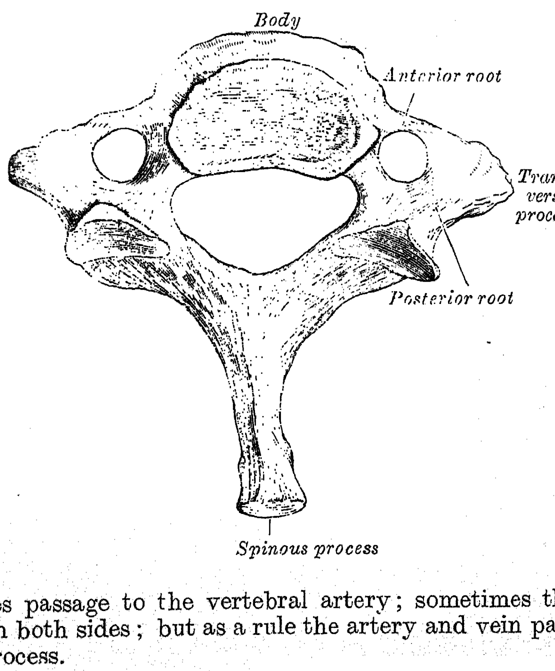
FIG. 252.—The second cervical vertebra, or epistropheus. Right lateral aspect.



behind the articular processes ; the *inferior* are in front of the articular processes, as in the typical cervical vertebræ. The *spinous process* is large and very strong ; it is deeply channelled on its under surface, and has a bifid, tuberculated extremity.

The **seventh cervical vertebra** (fig. 253).—This vertebra is named the *vertebra prominens* because of its long and prominent spinous process. This process is thick, and nearly horizontal in direction ; it is not bifurcated, but ends in a tubercle to which the lower end of the ligamentum nuchæ is attached. The *transverse processes* are of considerable size, and their posterior roots are large and prominent ; the anterior roots are usually small and faintly marked, but occasionally they exist as separate bones, which extend lateralwards and forwards, and are known as *cervical ribs*. The upper surface of each transverse process has usually a shallow sulcus for the seventh cervical nerve, and the extremity of the process seldom presents more than a trace of division. The *superior articular facets* look almost directly backwards. The foramen transversarium is generally smaller than that in the other cervical vertebræ ; rarely it is double, sometimes it is absent. On the left side it occasionally gives passage to the vertebral artery ; sometimes the vertebral vein traverses it on both sides ; but as a rule the artery and vein pass in front of the transverse process.

FIG. 253.—The seventh cervical vertebra. Superior aspect.



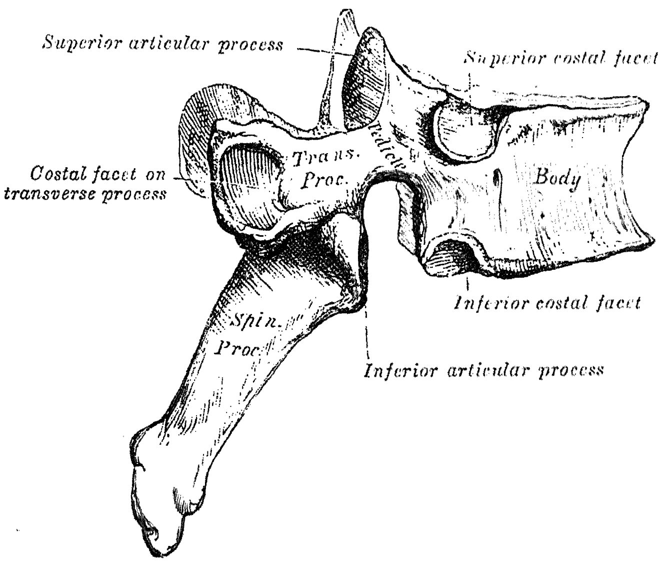
The Thoracic Vertebræ (Vertebræ Thoracales)

The **thoracic vertebræ** (fig. 254), twelve in number, increase successively in size from above downwards. All are distinguished by the presence of facets on the sides of the bodies, and all but the two lowest by facets on the transverse processes; the former articulate with the heads of the ribs, the latter with the tubercles of the ribs.

The *first, ninth, tenth, eleventh*, and *twelfth* thoracic vertebræ present certain peculiarities, and must be specially considered (fig. 255).

In a typical vertebra from the middle of the thoracic region the *body* is heart-shaped, and its anteroposterior and transverse diameters are about equal. It is slightly thicker behind than in front, flat above and below, convex from side to side in front, deeply concave behind, and slightly constricted laterally and in front. On either side are two costal facets, a superior, the

Fig. 254.—A typical thoracic vertebra. Right lateral aspect.

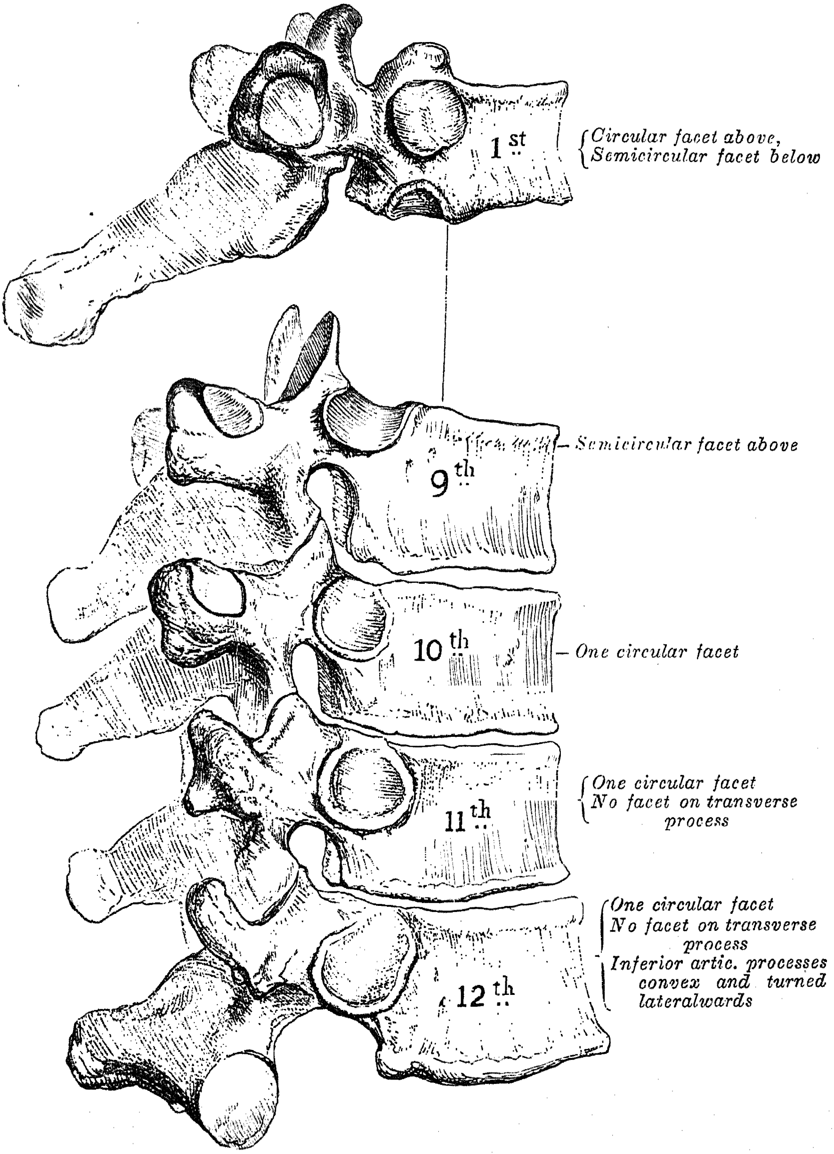


larger, near the root of the pedicle, and an inferior in front of the inferior vertebral notch; in the articulated vertebral column these facets form, with the intervertebral fibrocartilages, oval surfaces for the reception of the heads of the ribs. The *pedicles* are directed backwards and slightly upwards, and the inferior vertebral notches are of large size, and deeper than those of the cervical or lumbar vertebræ. The *laminæ* are broad and thick, and overlap those of subjacent vertebræ like tiles on a roof. The *vertebral foramen* is smaller than that of a cervical or lumbar vertebra, and is of a circular form. The *spinous process* is long, triangular on coronal section, directed obliquely downwards, and ends in a tuberculated extremity. The spinous processes overlap from the fifth to the eighth, but are less oblique in direction above and below these levels.* The *superior articular processes* are thin plates of bone projecting upwards from the junctions of the pedicles and laminæ; their articular facets are almost flat, and are directed backwards and a little lateralwards and upwards. The *inferior articular processes* are fused to a considerable extent with the laminæ, and project but slightly beyond the lower borders of the latter; their facets are directed forwards and a little medialwards and downwards.

* In quadrupeds the majority of the spinous processes of the thoracic vertebræ project upwards and backwards, while those of the lumbar region are directed upwards and forwards. The change in inclination is effected in one of the lower thoracic vertebræ, the spine of which points almost directly upwards. This vertebra is known as the *anticlinal*, and in man its representative is the eleventh thoracic.

The *transverse processes* arise from the arch behind the superior articular processes and pedicles; they are thick, strong, and of considerable length, directed obliquely backwards and lateralwards, and each ends in a clubbed extremity, on the front of which is a small costal facet, for articulation with the tubercle of a rib. In the upper six thoracic vertebræ the costal facets are concave,

FIG. 255.—The first, ninth, tenth, eleventh and twelfth thoracic vertebræ. Right lateral aspect.



and are placed on the anterior surfaces of the transverse processes; in the vertebræ from the seventh to the tenth inclusive the costal facets are flat and placed on the upper surfaces of the transverse processes.

The **first thoracic vertebra** (fig. 255) has on either side of the upper part of the body a complete facet for the head of the first rib, and at the lower part of the body a small facet for the upper half of the head of the second rib. The *body* resembles that of the seventh cervical vertebra, being broad transversely,

while its upper surface is concave in the same direction, and lipped on either side. The *superior articular surfaces* are directed upwards and backwards; the *spinous process* is thick, long, and almost horizontal. The *transverse processes* are long, and the superior vertebral notches are deeper than those of the other thoracic vertebræ.

The **ninth thoracic vertebra** (fig. 255) may have no inferior costal facets, but in some cases these are present.

The **tenth thoracic vertebra** (fig. 255) has usually a complete costal facet, placed partly on the lateral surface of the pedicle, for the head of the tenth rib, but the facet for the head of this rib is sometimes completed by the body of the ninth vertebra.

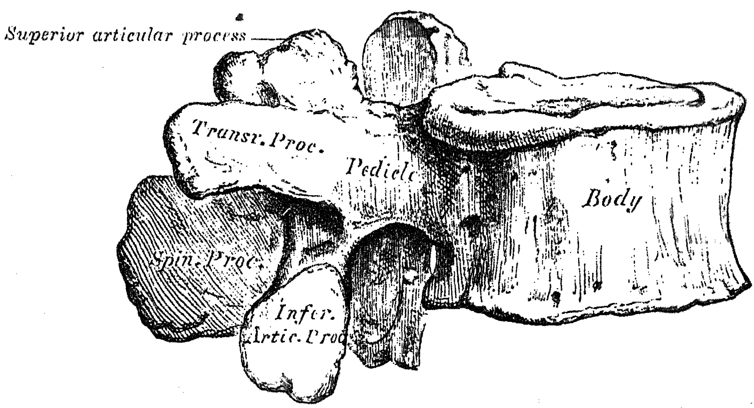
In the **eleventh thoracic vertebra** (fig. 255) the *body* approaches in form and size those of the lumbar vertebræ. The facets for the heads of the eleventh pair of ribs are large, and placed chiefly on the pedicles, which are thicker and stronger in this and the next vertebra than in other parts of the thoracic region. The *spinous process* is short, and nearly horizontal in direction. The *transverse processes* are very short, tuberculated at their extremities, and have no costal facets.

The **twelfth thoracic vertebra** (fig. 255) has the same general characteristics as the eleventh, but may be distinguished from it by its inferior articular surfaces which are convex and directed lateralwards like those of the lumbar vertebræ; by the body, laminæ, and spinous process, which resemble those of the lumbar vertebræ; and by each transverse process being a short irregular knob subdivided into superior, inferior, and lateral tubercles; the superior and inferior tubercles correspond to the mamillary and accessory processes of the lumbar vertebræ. Traces of similar tubercles are found on the transverse processes of the tenth and eleventh thoracic vertebræ.

The Lumbar Vertebræ (Vertebræ Lumbales)

The **lumbar vertebræ** (figs. 256, 257), five in number, are the largest of the movable vertebræ, and can be distinguished by the absence of foramina in their transverse processes, and of costal facets on the sides of the bodies.

Fig. 256.—A lumbar vertebra. Right lateral aspect.



The *body* is large, wider from side to side than from before backwards, and a little thicker in front than behind. It is flattened above and below, concave behind, and constricted in front and at the sides. The *pedicles* are strong, and directed backwards from the upper part of the body; consequently, the inferior vertebral notches are of considerable depth. The *laminæ* are broad, short, and strong; the *vertebral foramen* is triangular, larger than in the thoracic, but smaller than in the cervical region. The *spinous process* projects almost

horizontally backwards; it is somewhat quadrilateral in outline, with bulging posterior and inferior borders. The *superior and inferior articular processes*

FIG. 257.—A lumbar vertebra. Posterosuperior aspect.

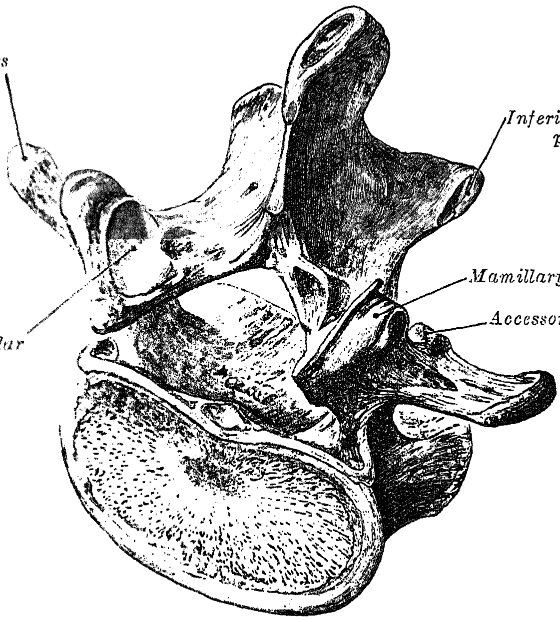
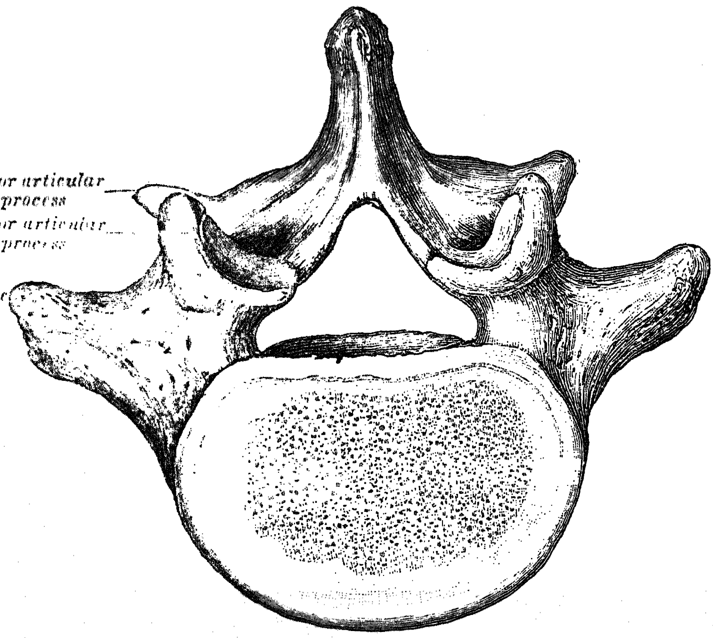


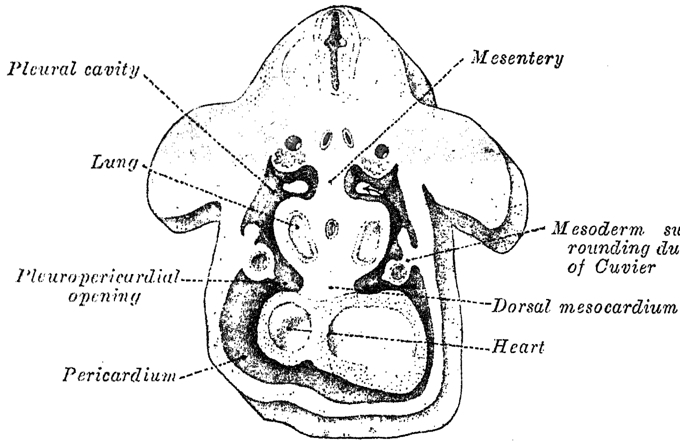
FIG. 258.—The fifth lumbar vertebra. Superior aspect.



project respectively upwards and downwards from the junctions of the pedicles and laminæ. The facets on the superior processes are concave, and look

embryonic part is obliterated by the expansion of the amnion, and the consequent fusion of the amniotic with the chorionic mesoderm (figs. 90, 91). From the pericardial (cephalic) part of the cœlom two canals or passages (pleural passages) extend

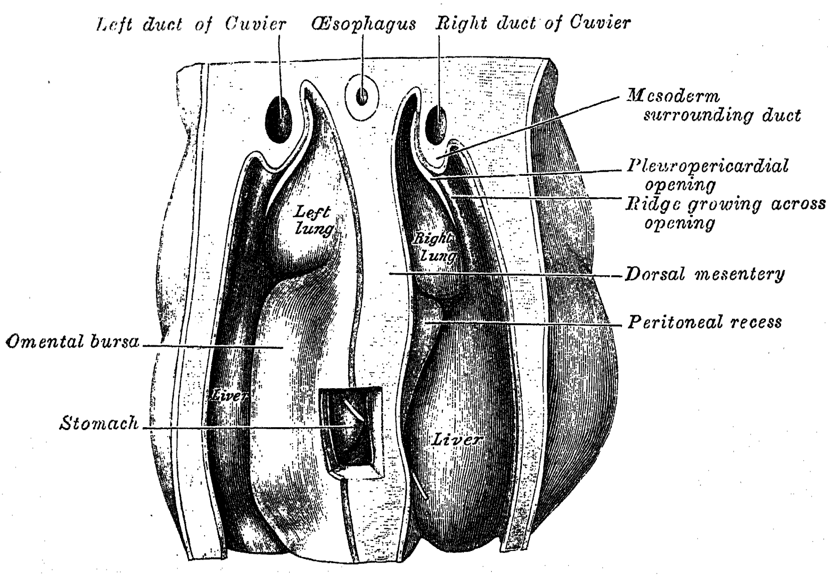
FIG. 221.—A transverse segment through the upper part of the cœlom of a human embryo about four weeks old. (Kollmann.)



The upper arrow is in the pleuroperitoneal, the lower in the pleuropericardial opening.

caudalwards and open into the peritoneal part of the cœlom (fig. 221). These pleural passages ultimately form the pleural cavities. Between the pleural passages is a mass of mesoderm continuous ventrally with that in which the umbilical veins are passing to the sinus venosus. A septum of mesoderm thus extends across the body of the embryo. It is attached in front to the body-wall between the pericardium and umbilicus; behind to the body-wall at the level of the second cervical segment;

FIG. 222.—The upper part of the cœlom of a human embryo of 6·8 mm. long. Dorsal aspect. (From a model by Piper.)

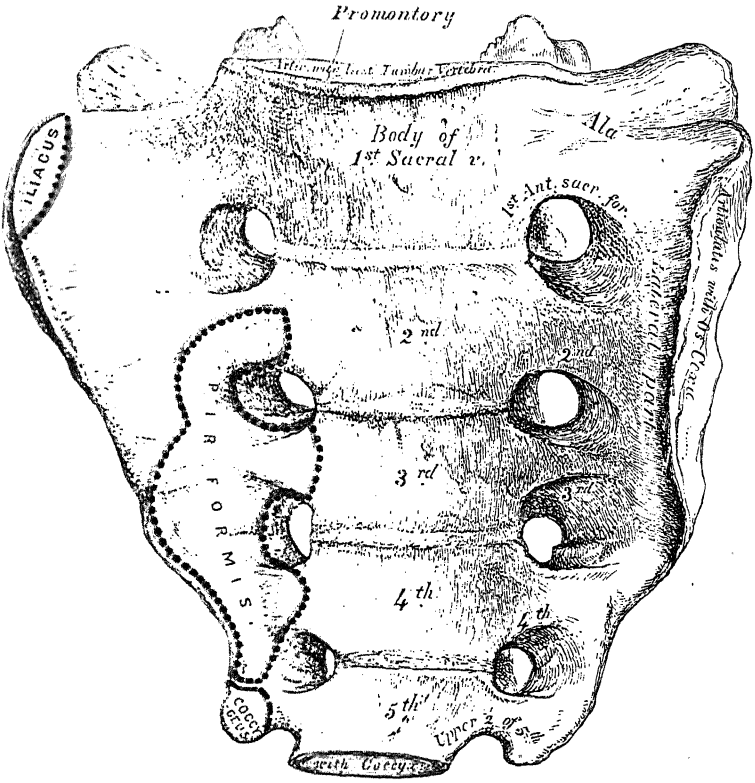


laterally it is deficient where the pericardial and peritoneal cavities communicate through the pleural passages; in the middle line it is perforated by the fore-gut. This partition is termed the *septum transversum*, and is at first a bulky plate of

in the recent state, are filled by the intervertebral fibrocartilages. In some specimens the union is more complete between the lower than between the upper segments.

The *dorsal surface* of the sacrum (fig. 260) is convex, and is narrower than the pelvic surface. In the middle line is the *median sacral crest,* surmounted by the rudimentary spinous processes of the upper three or four sacral vertebræ. On either side of this crest is the *sacral groove,* which gives origin to the Multifidus, the floor of the groove being formed by the united laminæ of the vertebræ. The laminæ of the fifth sacral vertebra, and sometimes those of the fourth, fail to meet behind, and thus a deficiency (*hiatus sacralis*) occurs in the posterior wall of the sacral canal. Lateral to either sacral groove is a linear

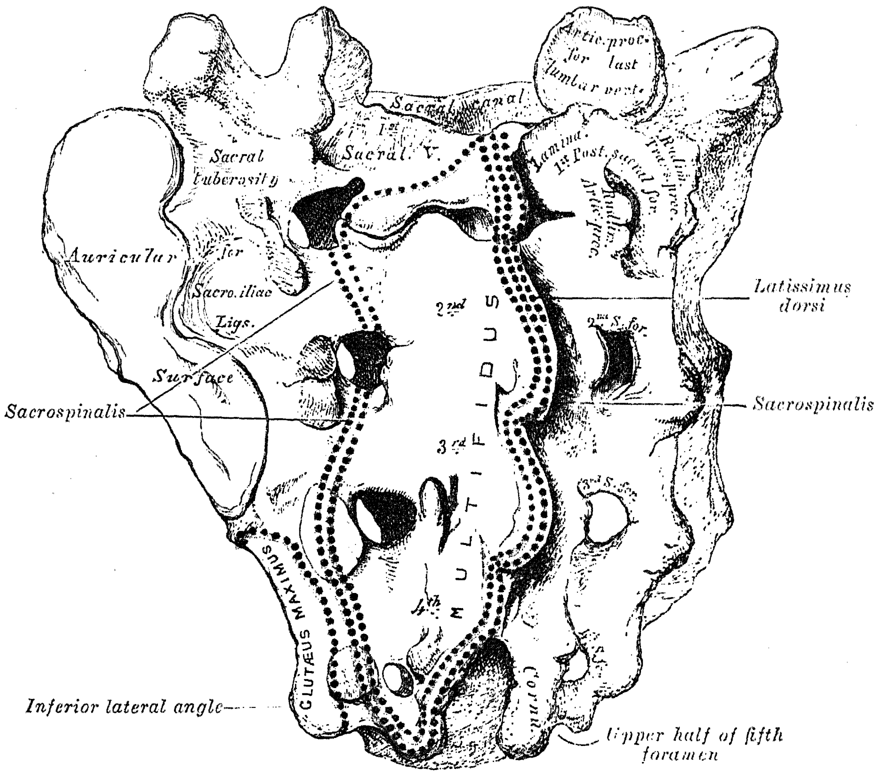
FIG. 259.—The sacrum. Pelvic aspect.



series of tubercles produced by the fusion of the articular processes, which together form the indistinct *sacral articular crests*. The articular processes of the first sacral vertebra are large, and their facets are oval or circular in shape, and concave from side to side; they look backwards and medialwards, and articulate with the facets on the inferior processes of the fifth lumbar vertebra. The tubercles which represent the inferior articular processes of the fifth sacral vertebra are prolonged downwards as rounded processes, which are named the *sacral cornua,* and are connected to the cornua of the coccyx. Lateral to the sacral articular crests are the four *posterior sacral foramina*; they transmit the posterior divisions of the sacral nerves, and are smaller in size and less regular in form than the anterior foramina. Lateral to the posterior sacral foramina are the *lateral sacral crests,* formed by the fused transverse processes of the sacral vertebræ. The transverse tubercles of the first sacral vertebra are large and very distinct; they and the transverse tubercles of the second vertebra, give attachment to the short posterior sacro-iliac ligaments; those of the third vertebra give attachment to the long posterior sacro-iliac ligaments; and those of the fourth and fifth to the sacrotuberous ligaments.

The *lateral surfaces* of the sacrum (fig. 261) are broad above, and narrow below. On the broad upper part of each is an ear-shaped surface, the *auricular surface*, for articulation with the ilium, and behind this is a rough area, the *sacral tuberosity*, on which are three deep impressions, for the attachment of the interosseous sacro-iliac ligament; the thin, lower part gives attachment to the sacrotuberous and sacrospinous ligaments, to some fibres of the Glutæus maximus behind, and of the Coccygeus in front. It ends below in a projection called the *inferior lateral angle*; the notch on the medial side of this angle is converted into a foramen by the transverse process of the first piece of the coccyx, and transmits the anterior division of the fifth sacral nerve.

FIG. 260.—The sacrum. Dorsal aspect.



The *base* of the sacrum (fig. 262) is transversely expanded, and is directed upwards and forwards. In its central part is the large oval upper surface of the body of the first sacral vertebra, which is connected with the under surface of the body of the last lumbar vertebra by an intervertebral fibrocartilage; the anterior projecting edge of the body is named the *promontory*. Behind the body is the superior orifice of the sacral canal, triangular in shape and completed posteriorly by the arch of the first sacral vertebra. On either side of the body is a large triangular plate called the *ala sacralis*. The upper surface of the ala is slightly concave from side to side, and convex from before backwards, and in the articulated pelvis is continuous with the iliac fossa. The posterior one-third of the ala represents the transverse process, and the anterior two-thirds the costal process of the first sacral vertebra. The superior articular processes are attached to the body of the first sacral vertebra and to the alæ by short thick pedicles; they are oval, concave, directed backwards and medialwards, like the superior articular processes of the lumbar vertebræ. On the upper surface of either pedicle is a vertebral notch, which forms the lower part of the foramen between the last lumbar and first sacral vertebræ.

The *apex* of the sacrum, directed downwards, is truncated and carries an oval facet for articulation with the coccyx.

FIG. 261.—The sacrum and coccyx. Right lateral aspect.

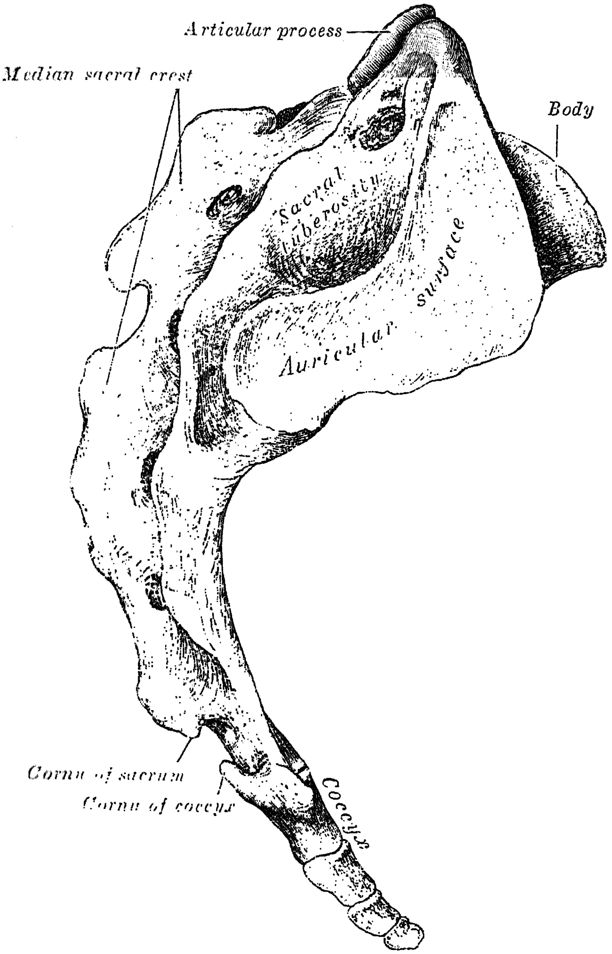
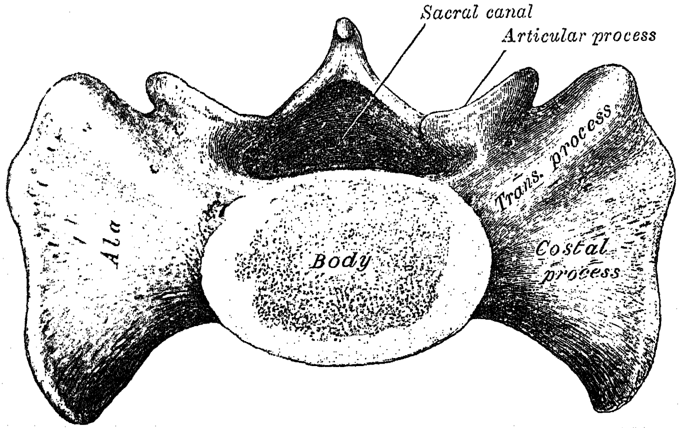


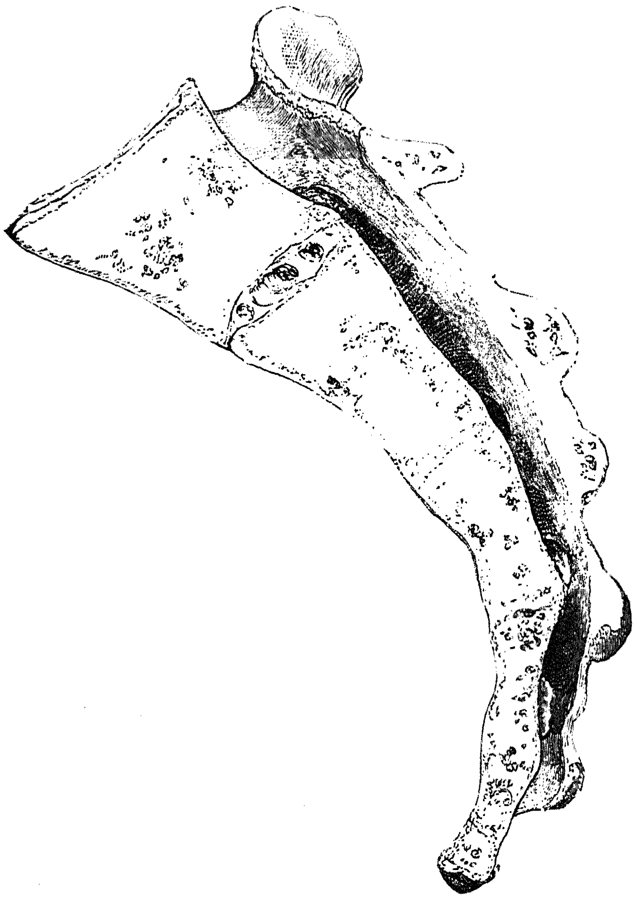
FIG. 262.—The sacrum. Superior aspect.



The *sacral canal* (fig. 263) lodges the sacral nerves and runs through the greater part of the length of the bone; above, it is a closed canal, triangular in cross section; below, its posterior wall is incomplete, owing to the non-development of the laminæ and spinous processes. Its walls are perforated by the anterior and posterior sacral foramina through which the nerves emerge.

Differences in the sacrum of the male and female.—In the female the sacrum is shorter and wider than in the male; the upper part of the bone is flattened, and the lower part curved abruptly forwards. In the male the

Fig. 263.—A median sagittal section through the sacrum.



curvature is more evenly distributed over the whole length of the bone. In the female the bone is directed more obliquely backwards than in the male; this increases the size of the pelvic cavity and renders the sacrovertebral angle more prominent. In the female the auricular surface for articulation with the ilium is shorter than that in the male, extending along the sides of the first and second sacral vertebræ only; in the male it is continued down to the middle or lower limit of the third vertebra.

Structure.—The sacrum consists of spongy substance enveloped by a thin layer of compact bone.

Variations.—The curvature of the sacrum varies considerably in different specimens of the same sex. In some cases the bone consists of six vertebræ, in others of four. The transverse process of the first sacral segment may not be joined to the rest of the ala on one or both sides, and a considerable part of the posterior wall of the sacral canal may be wanting, in consequence of the imperfect development of the laminæ and spinous processes.

The Coccyx (Os Coccygis)

The **coccyx** (figs. 264, 265) is a small, triangular bone consisting usually of four rudimentary vertebræ, but the number may be increased to five or reduced to three; it forms a pointed apex for the sacral wedge.

The *first coccygeal vertebra* is the largest and often exists as a separate piece. On the upper surface of its central part or body, is an oval facet for articulation with the apex of the sacrum. Two processes, named *coccygeal cornua*, project upwards from the posterolateral parts of the body; they are the homologues of the pedicles and superior articular processes of the movable vertebræ. They ascend to articulate with the sacral cornua, and, on either side, form part of the margin of the intervertebral foramen for the fifth sacral nerve. A rudimentary transverse process projects lateralwards and slightly upwards from either side of the body. It is flattened from before backwards, and often ascends to articulate with the inferior lateral angle of the sacrum, thus completing the foramen for the passage of the anterior division of the fifth sacral nerve; the posterior division of this nerve descends on the back of the transverse process.

Fig. 264.—The coccyx. Anterior aspect.

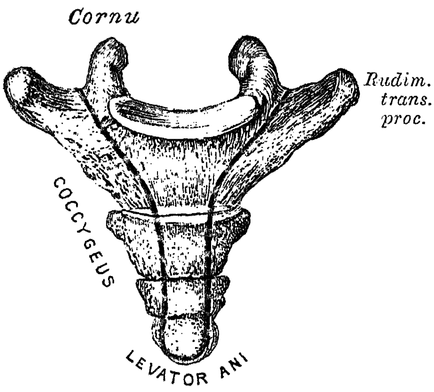
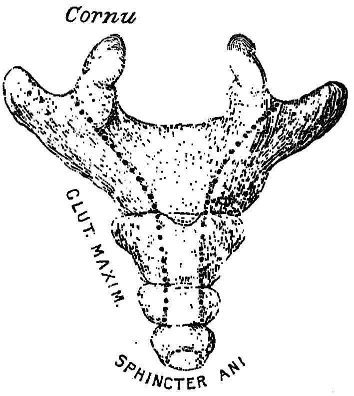


Fig. 265.—The coccyx. Posterior aspect.



The *second*, *third*, and *fourth coccygeal vertebræ* diminish successively in size, and are usually fused with one another. The second shows traces of transverse processes and pedicles; the third and fourth represent only rudimentary vertebral bodies, and are mere nodules of bone.

The filum terminale of the medulla spinalis is attached to the posterior surface of the first segment. The Glutæus maximus arises from the posterior surfaces of the first three segments, and the Sphincter ani externus from the last. The Coccygei and Levatores ani are attached to the thin lateral edges, and to the adjoining parts of the anterior surface of the bone.

The ossification of the vertebral column.—Each typical vertebra is ossified from three primary centres (fig. 266), two for the vertebral arch, and one for the body.* Ossification of the vertebral arches begins in the upper cervical vertebræ about the seventh or eighth week of fœtal life, and gradually extends down the column. The centres first appear in the situations where the transverse processes afterwards project, and spread backwards to the spinous process, forwards into the pedicles, and lateralwards into the transverse processes. Ossification of the bodies begins in the lower thoracic vertebræ about the eighth week of fœtal life, and subsequently extends upwards and downwards along the column. The centre for the body does not give rise to the whole of the body of the adult vertebra, the posterolateral portions of which are ossified from the centres for the vertebral arch. The body of a vertebra during the first few years of life shows, therefore, two synchondroses (*neurocentral synchondroses*) traversing it along the planes of junction of these three centres (fig. 267). In the thoracic region the costal facets on the bodies lie behind the neurocentral synchondroses. At birth a vertebra consists of three pieces, viz. the body and the halves of the vertebral arch. During the first year the halves of the

* The body is occasionally ossified from two lateral centres which sometimes fail to unite.

arch unite behind, union taking place first in the lumbar region and then extending upwards through the thoracic and cervical regions. In the upper cervical vertebræ the bodies unite with the arches about the third year, but in the lower lumbar vertebræ union is not completed until the sixth year. Until puberty, the upper and under surfaces of the bodies and the ends of the transverse and spinous processes are cartilaginous, but about the sixteenth year five secondary centres appear, one for the tip of either transverse process, one for the end of the spinous process, and two annular epiphysial discs, for the circumferential parts of the upper and lower surfaces of the body (figs. 267, 268). The costal articular facets arise as extensions of the annular epiphysial discs (Dixon).* These secondary centres fuse with the rest of the bone about the age of twenty-five years. In the bifid spines of the cervical vertebræ there are two secondary centres.

Exceptions to this mode of ossification occur in the first, second, and seventh cervical vertebræ, and in the lumbar vertebræ.

The **atlas,** or first cervical vertebra, is usually ossified from three centres (fig. 269). One appears in either lateral mass about the seventh week of fœtal life, and gradually extends into the posterior arch, where the two unite between the third and fourth years, either directly or through the medium of a separate centre. At birth, the anterior arch consists of cartilage; in this a separate centre appears about the end of the first year, and unites with the lateral masses between the sixth and eighth years—the lines of union extending across the anterior portions of the superior articular facets. Occasionally the anterior arch is formed by the forward extension and ultimate union of the centres for the lateral masses; sometimes it is ossified from two laterally placed centres.

The **epistropheus,** or second cervical vertebra, is ossified from five primary and two secondary centres (fig. 270). The vertebral arch is ossified from two primary

Fig. 266.—The ossification of a typical vertebra.

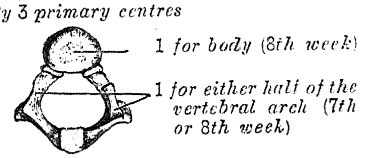


Fig. 267.

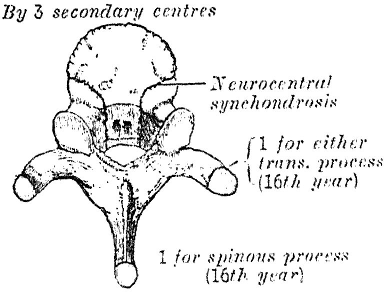
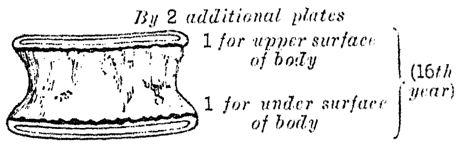


Fig. 268.



Exceptional cases

Fig. 269.—The ossification of the atlas.

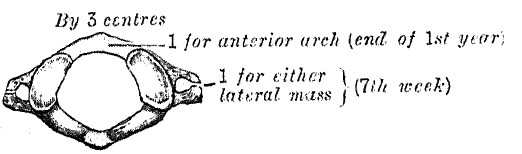


Fig. 270.—The ossification of the epistropheus.

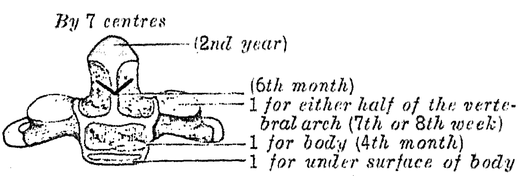
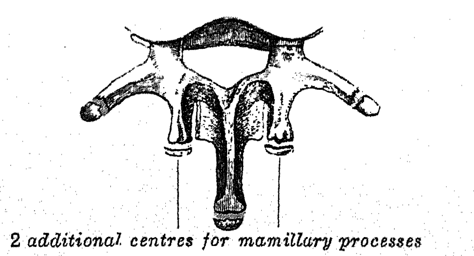


Fig. 271.—The ossification of a lumbar vertebra.



* A. Francis Dixon, *Journal of Anatomy,* vol. lv., October 1920.

centres, and the body from one, as in a typical vertebra ; the centres for the arch appear about the seventh or eighth week of fœtal life, the centre for the body about the fourth or fifth month. The dens or odontoid process represents the body of the atlas, and is chiefly ossified from two laterally-placed centres ; these appear about the sixth month of fœtal life, and join before birth to form a conical mass, deeply cleft above. A wedge-shaped piece of cartilage fills the cleft and forms the summit of the process ; in this cartilage a centre appears about the second year and unites with the main mass of the dens about the twelfth year. The base of the dens is separated from the body of the epistropheus by a cartilaginous disc, the circumference of which ossifies, but the centre remains cartilaginous until advanced age ; in this cartilaginous disc, rudiments of the lower epiphysial lamella of the atlas and the upper epiphysial lamella of the epistropheus may sometimes be found. In addition to these centres there is one for a thin epiphysial plate on the under surface of the body of the bone.

The **seventh cervical vertebra.**—The costal processes of this vertebra are usually ossified from separate centres which appear about the sixth month of fœtal life, and join the body and transverse processes between the fifth and sixth years. As already stated (p. 169), the costal processes may persist as separate pieces, and grow lateralwards and forwards, to constitute cervical ribs.

Separate ossific centres have also been found in the costal processes of the fourth, fifth, and sixth cervical vertebræ.

The **lumbar vertebræ** (fig. 271) have each two additional centres, for the mamillary processes.

The **sacrum** (figs. 272 to 275).—Each sacral vertebra is ossified from three primary centres, one for the body and two for the vertebral arch. Two epiphysial plates are ossified for each body, one for the upper and the other for the lower surface.

The anterior portions of the lateral parts of the sacrum have six additional (costal) centres, two for each of the first three vertebræ ; these appear above and lateral to the anterior sacral foramina (figs. 272, 273).

Two epiphysial plates are developed on either lateral surface of the sacrum (figs. 274, 275) ; one for the auricular surface, and another for the thin edge of bone below this surface.

Fig. 272.—The ossification of the sacrum and coccyx.

At birth

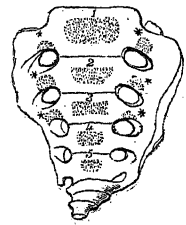


Fig. 273.

At 4½ years

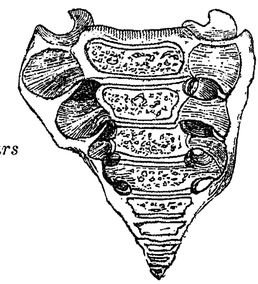


Fig. 274.

The two epiphysial plates for each lateral surface are marked by asterisks.

At 25th year

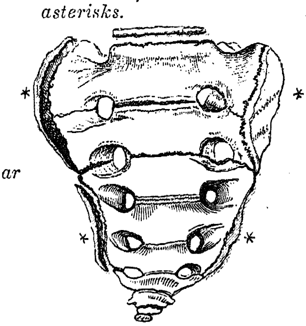
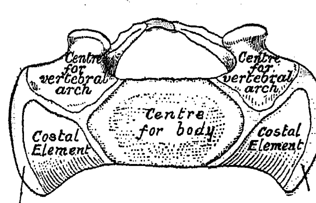


Fig. 275.—The base of the sacrum of an adolescent.



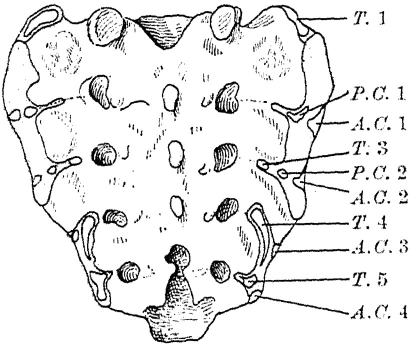
The ends of the spinous processes of the upper three sacral vertebræ are sometimes developed from separate epiphyses, and Fawcett * has pointed out that a number of epiphyses are present in the sacrum at the eighteenth year (fig. 276). These are distributed as follows : One for each of the two mamillary processes of the first sacral vertebra ; twelve, six on either side, in connexion with the costal processes (two each—an anterior and a posterior—for the first and second, and

* E. Fawcett, *Anatomischer Anzeiger*, Bd. xxx., 1907.

one each—an anterior—for the third and fourth vertebræ; and eight, four on either side, for the transverse processes, one each for the first, third, fourth and fifth. He is also of opinion (1) that the auricular facets on the lateral surfaces of the sacrum are in the main formed by the development and fusion of the costal epiphyses of the first and second sacral vertebræ, and (2) that the lower part of each lateral surface is formed by the extension and union of the costal epiphyses of the third and fourth, with the epiphyses of the transverse processes of the fourth and fifth, sacral vertebræ.

The periods of ossification of the sacrum.—The centres for the bodies of the first, second and third sacral vertebræ appear towards the end of the third month, and those for the bodies of the fourth and fifth vertebræ between the fifth and eighth months of fœtal life. The centres for the vertebral arches appear about the fifth month, and those for the costal processes of the lateral parts of the bone between the sixth and eighth months of fœtal life. In the lower vertebræ the arches fuse with the bodies in the second year; in the first vertebra fusion does not occur until the fifth or sixth year. About the sixteenth year the epiphysial plates for the upper and under surfaces of the bodies are formed; and between the eighteenth and twentieth years those for the lateral surfaces of the bone make their appearance. During early life, the bodies of the sacral vertebræ are separated from each other by intervertebral fibrocartilages, but about the eighteenth year the bodies of the two lower vertebræ become united by bone, and the process of bony union gradually extends upwards, with the result that between the twenty-fifth and thirtieth years of life all the vertebræ are united (fig. 263).

FIG. 276.—The epiphyses of the costal and transverse processes of the sacrum at the eighteenth year. (E. Fawcett.)



A.C. 1, 2, 3, 4, Anterior epiphyses for first, second, third and fourth costal processes. *P.C.* 1, 2, Posterior epiphyses for first and second costal processes. *T.* 1, 3, 4, 5, Epiphyses for the first, third, fourth and fifth transverse processes.

The **coccyx.**—Each segment of the coccyx is ossified from one centre. The centres appear in the following order: in the first segment between the first and fourth years; in the second between the fifth and tenth years; in the third between the tenth and fifteenth years; in the fourth between the fourteenth and twentieth years. A secondary centre for each coccygeal cornu, and a pair of epiphysial plates for each of the rudimentary bodies have been described. As age advances, the segments unite with one another, the union between the first and second being frequently delayed until after the age of twenty-five or thirty years. At a late period of life, especially in females, the coccyx often fuses with the sacrum.

The Vertebral Column as a Whole

The **vertebral column** is situated in the median line. at the posterior part of the trunk. Its average length in the male is about 71 cm.; of this the cervical part measures 12·5 cm., the thoracic 28 cm., the lumbar 18 cm., and the sacrum and coccyx 12·5 cm. The average length of the female vertebral column is about 61 cm.

The curves of the vertebral column.—Viewed laterally (fig. 277), the vertebral column presents cervical, thoracic, lumbar, and pelvic curves. The thoracic and pelvic curves are termed primary curves, because they alone are present during fœtal life. The cervical and lumbar curves are secondary or compensatory, and are developed after birth, the cervical curve when the child is able to hold up its head (at three or four months), and to sit upright (about nine months), the lumbar at twelve or eighteen months when the child begins to walk. The *cervical* curve is convex forwards, and is the least marked of the four; it begins at the atlas, and ends at the middle of the second thoracic vertebra. The *thoracic* curve is concave forwards, and extends from the

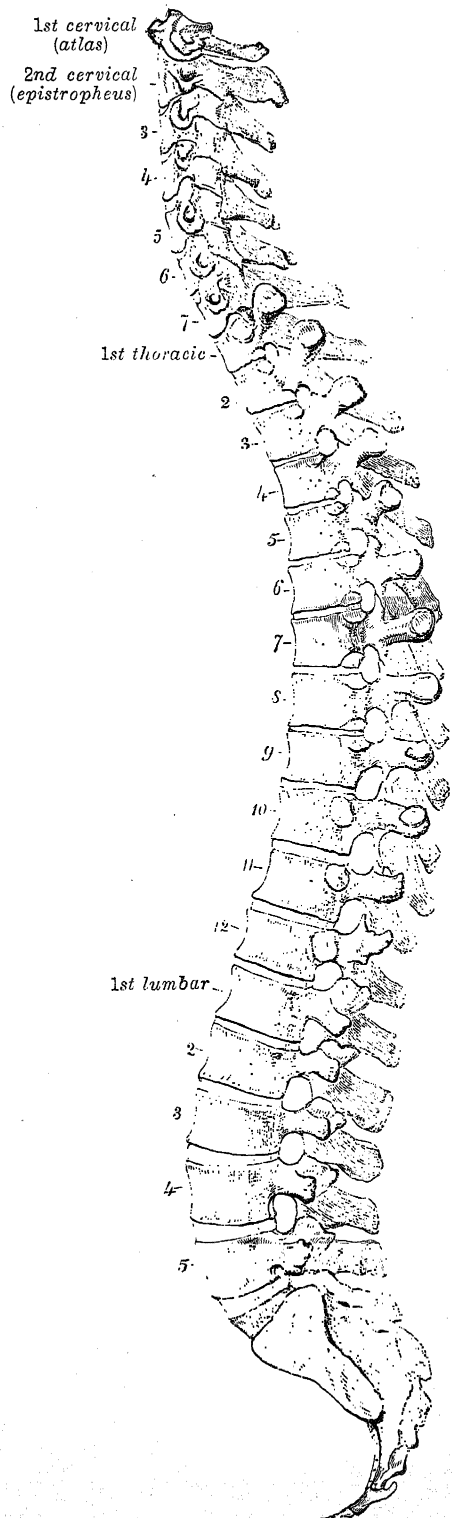
middle of the second to the middle of the twelfth thoracic vertebra. The *lumbar* curve is convex anteriorly and is more pronounced in the female than in the male; it reaches from the middle of the last thoracic vertebra to the sacrovertebral angle, and the convexity of the lower three segments is greater than that of the upper two. The *pelvic* curve extends from the sacrovertebral articulation to the apex of the coccyx; its concavity is directed downwards and forwards.

In the upper part of the thoracic region of the vertebral column there is a slight *lateral* curvature, with its convexity directed towards the right side in right-handed persons. Some regard this curve as being due to the greater use and muscularity of the right arm, and in support of this explanation it has been found that in left-handed individuals the convexity of the curve is directed towards the left side. Others regard it as being produced by the aortic arch and upper part of the descending thoracic aorta—a view which is supported by the fact that in cases where the viscera are transposed and the aorta is consequently on the right side, the convexity of the curve is directed to the left.

The *anterior surface* of the vertebral column.—When viewed from in front, the width of the bodies of the vertebræ is seen to increase from the second cervical to the first thoracic; there is then a slight diminution in the next three vertebræ; below this there is again a gradual and progressive increase in width as low as the sacrovertebral angle. From this level there is a rapid diminution, to the apex of the coccyx.

The *posterior surface* of the vertebral column presents in the median line the spinous processes. In the cervical region (with the exception of the second and seventh vertebræ) these are short and horizontal, with bifid ends. In the upper part of the thoracic region they are directed obliquely downwards; in the middle part they are long and almost vertical; in the lower part of the thoracic region and in the lumbar region they are nearly horizontal. They are separated by considerable intervals in the cervical and lumbar regions, but are closely

Fig. 277.—The vertebral column. Left lateral aspect.



approximated in the middle of the thoracic region. Occasionally a spinous process may deviate from the median line—a fact to be remembered in practice, as irregularities of this sort are attendant also on fractures or displacements of the vertebral column. At the sides of the spinous processes are the *vertebral grooves* which lodge the deep muscles of the back. In the cervical and lumbar regions these grooves are shallow and are formed by the laminæ of the vertebræ; in the thoracic region they are deep and wide, and are formed by the laminæ and transverse processes. Lateral to the vertebral grooves are the articular processes, and still more lateral the transverse processes. In the thoracic region, the transverse processes stand backwards, on a plane considerably behind that of the same processes in the cervical and lumbar regions. In the cervical region, the transverse processes are placed in front of the articular processes, lateral to the pedicles, and between the intervertebral foramina. In the thoracic region they are behind the pedicles, intervertebral foramina, and articular processes. In the lumbar region they are in front of the articular processes, but behind the intervertebral foramina.

The *lateral surfaces* of the vertebral column are separated from the posterior surface by the articular processes in the cervical and lumbar regions, and by the transverse processes in the thoracic region. In front are the sides of the bodies of the vertebræ, marked in the thoracic region by the facets for articulation with the heads of the ribs. Between the pedicles are the intervertebral foramina, oval in shape, smallest in the cervical and upper part of the thoracic regions, and gradually increasing in size to the last lumbar; these foramina transmit the spinal nerves and vessels.

The *vertebral canal* follows the curves of the column; it is large and triangular in the cervical and lumbar regions, where movement is free, but small and circular in the thoracic region, where motion is more limited.

Applied Anatomy.—Occasionally the coalescence of the laminæ is not completed, and consequently a cleft is left in the arches of the vertebræ, through which a protrusion of the spinal membranes (dura mater and arachnoid), and generally of the medulla spinalis and pia mater, takes place, constituting the malformation known as *spina bifida*. This condition is most common in the lumbosacral region, but it may occur in the thoracic or cervical region, or the arches throughout the whole length of the canal may remain incomplete.

Although there is only a very limited amount of movement between any two contiguous vertebræ, there is a considerable range of movement in the vertebral column as a whole. The intervertebral fibrocartilages act as buffers between the different segments and counteract or neutralize the effect of jars or shocks which may be applied to the column; for example, dropping from a height on to the feet rarely causes concussion of the brain or spinal medulla. The security of the column is also provided for by its disposition in curves, enabling it to bend without breaking. The vertebræ are so firmly united to one another that violence applied to the column is more likely to produce fracture or dislocation than a tearing of ligaments.

Fracture-dislocations of the vertebral column are more frequently caused by indirect than by direct violence. When produced by indirect violence, the upper segment is driven forwards on the lower, and the spinal medulla is compressed between the body of the vertebra immediately below, and the arch of the vertebra immediately above, the injury. Since the spinal medulla ends at the level of the upper border of the second lumbar vertebra it follows that partial dislocations, or gunshot wounds, below this level are less serious than those above it.

The normal position of the vertebral column may be altered either by the formation of new curvatures or by an increase of some of the normal ones. In many cases, notably in rapidly growing adolescents, the deformity results from weakness of the supporting muscles which are unable to keep the vertebræ firmly applied to one another, and alterations in the disposition of the column are produced by the weight of the body. In later life the persistent use of faulty positions (e.g. in shoemakers, tailors, etc.) or the carrying of weights suspended from the trunk (e.g. in hawkers) may distort the vertebral column. In other cases the changes in the curvatures may be the result of diseases of the vertebræ or their ligaments (e.g. tuberculosis, rheumatism, etc.). Sometimes the deviations result mechanically from the effects of disease in other parts (e.g. in cases of shortening of one leg from hip-joint disease, or in cases of adhesions in the thorax from an old empyema). Changes in the curvatures of the vertebral column are multiple since secondary (compensatory) curves form to restore the balance of the body.

The chief forms of abnormal curvatures are scoliosis, kyphosis and lordosis. In *scoliosis* the column is bent to one side, and this is accompanied by a rotation of the vertebral bodies round a vertical axis. In *kyphosis* the thoracic curve is increased, while in *lordosis* the deformity is an exaggeration of the lumbar curve.

Laminectomy.—The operation of laminectomy is performed in cases of pressure on the medulla spinalis, where the continuity of the nerve-tracts has not been completely destroyed. It consists of cutting down on and removing the laminæ and spinous processes in the affected region, so as to relieve the medulla spinalis from pressure; but it is useless in cases of complete destruction of this structure. Laminectomy is chiefly performed (i) for fracture-dislocation; (ii) for localised pressure in cases of spinal caries, the object here being to remove the laminæ against which the medulla spinalis is pressed by the inflammatory mass, and (iii) for the removal of tumours growing inside the vertebral canal and compressing the medulla spinalis. If such cases be taken early, very satisfactory results are obtained.

The subarachnoid cavity ends at the level of the lower border of the second sacral vertebra; the lower part of the sacrum may therefore be removed to expose growths or tumours of the rectum without opening into this cavity.

The Sternum

The **sternum** (figs. 278 to 280) is a long flat bone, forming the middle portion of the anterior wall of the thorax. Its average length is about 17 cm., and is rather greater in the male than in the female. Its upper end supports the clavicles, and its margins articulate with the cartilages of the first seven pairs of ribs. It consists of three parts, named from above downwards, the *manubrium*, the *body*, and the *xiphoid process*; in early life the body consists of four segments or *sternebræ*. In its natural position the inclination of the bone is oblique from above, downwards and forwards. It is slightly convex in front, and concave behind; it is broad above, narrow at the junction of the manubrium with the body, below which it gradually widens as far as the level of the articulations of the cartilages of the fifth ribs, and then narrows quickly to its lower extremity.

The **manubrium sterni** is of a somewhat triangular form, broad and thick above, narrow below at its junction with the body. Its *anterior surface*, convex from side to side, concave from above downwards, is smooth, and affords attachment on either side to the sternal origins of the Pectoralis major and Sternocleidomastoideus. Its *posterior surface*, concave and smooth, gives origin on either side to the Sternohyoideus and Sternothyreoideus. The *superior border* is thick, and presents at its centre the *jugular notch*; on either side of this notch is an oval articular surface, directed upwards, backwards, and lateralwards, for articulation with the sternal end of the clavicle. The *inferior border*, oval and rough, is covered in the recent state with a thin layer of cartilage, for articulation with the upper end of the body. The *lateral borders* are each marked above by a depression for the reception of the first costal cartilage, and below by a small articular facet, which, with a similar one on the upper angle of the body, forms a notch for the sternal end of the costal cartilage of the second rib. Between the depression for the first costal cartilage and the facet for the second is a narrow, curved edge, which slopes from above downwards and medialwards.

The **body** of the sternum, longer, narrower, and thinner than the manubrium, attains its greatest breadth close to the lower end. Its *anterior surface*, nearly flat, is directed forwards and upwards, and is marked by three transverse ridges opposite the third, fourth, and fifth articular depressions.* It affords attachment on either side to the sternal origin of the Pectoralis major. A *sternal foramen*, of varying size and form, is occasionally seen at the junction of the third and fourth pieces of the body. The *posterior surface*, slightly concave, is also marked by three transverse lines, less distinct, however, than those on the anterior surface; from its lower part, on either side, the Transversus thoracis takes origin. The *upper end* is oval and articulates with the manubrium, the junction of the two forming the *sternal angle* (*angulus Ludovici* †). The *lower end* is narrow, and articulates with the xiphoid process. Each *lateral border* (fig. 280), at its superior angle, has a small facet, which with a

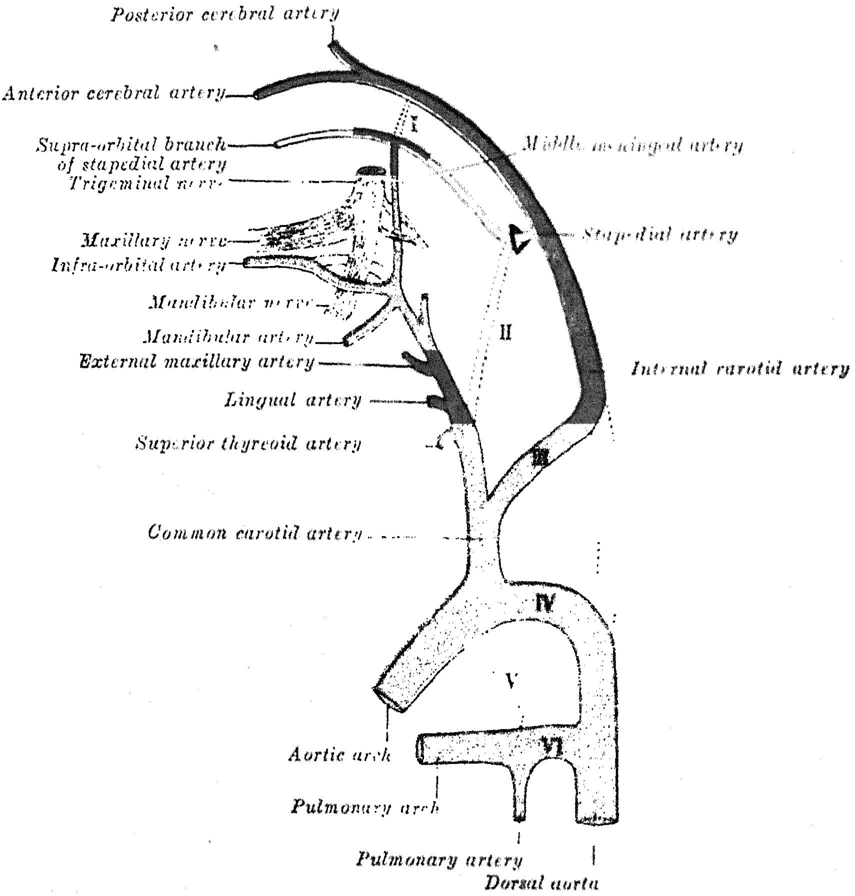
* Paterson (*The Human Sternum*, 1904) found that these ridges were absent in 26·7 per cent.; that a ridge existed opposite the third costal cartilage in 69 per cent.; opposite the fourth in 39 per cent.; and opposite the fifth in 4 per cent.

† Named after the French surgeon Antoine Louis, 1723-1792. The Latin term *angulus Ludovici* is not infrequently mistranslated into English as 'the angle of Ludwig.'

each vessel a capillary network forms, and by the enlargement of definite paths in this network the larger arteries and veins are developed. The branches of the main arteries are not always simple modifications of the vessels of the capillary network, but may arise as new outgrowths from the enlarged stem.

It has been seen (p. 111) that each primitive aorta consists of a ventral and a dorsal part which are continuous through the first aortic arch. The dorsal aortæ at first run backwards separately on either side of the notochord, but in the third week they fuse from about the level of the fourth thoracic to that of the fourth lumbar segment to form a single trunk, the descending aorta. The first aortic

FIG. 183.—A diagram showing the origins of the main branches of the carotid arteries. (Founded on Tandler by T. H. Bryce.) (From Quain's Elements of Anatomy, vol. i., Embryology.)



arches run through the mandibular arches, and behind them five additional pairs are developed within the corresponding visceral arches; so that, in all, six pairs of aortic arches are formed (figs. 180, 182). The fifth arches are very transitory vessels connecting the truncus arteriosus with the dorsal ends of the sixth arches. The first and second arches pass between the ventral and dorsal aortæ, while the others arise at first by a common stem from the truncus arteriosus, but end separately in the dorsal aortæ. As the neck elongates, the ventral aortæ are drawn out, and the third and fourth arches arise directly from these vessels.

In fishes the aortic arches persist and give off branches to the gills, in which the blood is oxygenated. In mammals some of the arteries remain as permanent structures, while others disappear or are obliterated (fig. 182).

The ventral aortæ.—These persist on both sides. The right ventral aorta forms, as far as the fourth aortic arch, the innominate artery, and beyond that arch the

The **xiphoid process** is the smallest piece of the sternum; it is thin and elongated, cartilaginous in youth, but more or less ossified at its upper part in the adult. Its *anterior surface* affords attachment on either side to the anterior costoxiphoid ligament and a small part of the Rectus abdominis; its *posterior surface*, to the posterior costoxiphoid ligaments and to some of the fibres of the Diaphragm and Transversus thoracis; its *lateral borders*, to the aponeuroses of the abdominal muscles. Above, it articulates with the lower end of the body of the bone, and on the front of each superior angle is a facet for a part of the cartilage of the seventh rib; the linea alba is attached to its pointed lower end.

The xiphoid process varies greatly; it may be broad and thin, pointed, bifid, perforated, curved, or deflected to one or other side.

Fig. 279.—The sternum. Posterior aspect.

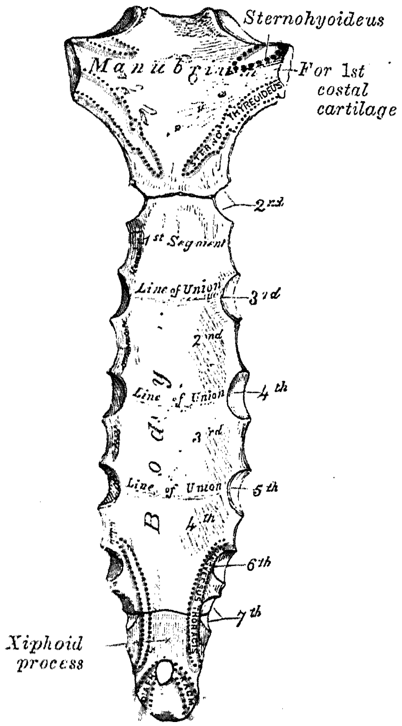
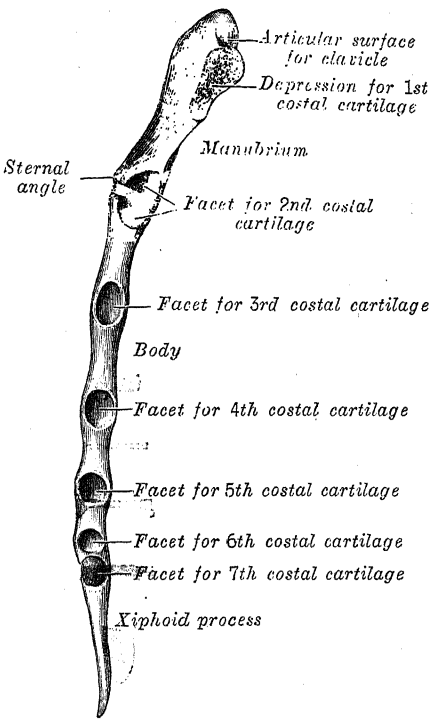


Fig. 280.—The sternum. Lateral aspect.



Structure.—The sternum is composed of highly vascular spongy substance covered by a layer of compact bone which is thickest on the manubrium between the articular facets for the clavicles.

Ossification.—The sternum originally consists of two cartilaginous *sternal plates*, one on either side of the median plane. Opposite the first seven pairs of ribs these plates fuse with one another in the middle line to form the cartilaginous sternum, which is ossified from six centres: one for the manubrium, four for the body, and one for the xiphoid process (fig. 281). These centres appear in the intervals between the articular depressions for the costal cartilages, in the following order: in the manubrium and first piece of the body, during the sixth month of fœtal life; in the second and third pieces of the body, during the seventh month of fœtal life; in the fourth piece, shortly before birth; and in the xiphoid process, in the third year or much later.* Two small episternal centres sometimes appear, one on either side of the jugular notch; they are probably vestiges of the episternal bone of the monotremata and lizards. The manubrium may have two, three, or more centres;

* Paterson (*op. cit.*) found the fourth or lowest centre for the body present only in 26·9 per cent. of cases.

when two are present, one is generally situated above the other, the upper being the larger. The first segment of the body has seldom more than one centre; but the second, third, and fourth segments are often ossified from two laterally placed centres, and if these fail to join the foramen or fissure which is occasionally seen in this part of the bone results. Union between the centres of the body begins about puberty, and proceeds from below upwards (fig. 282); by the age of twenty-five they are all united. The xiphoid process usually fuses with the body about

FIG. 281.—The ossification of the sternum.

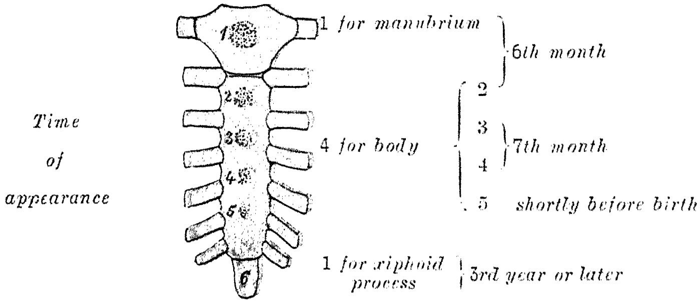
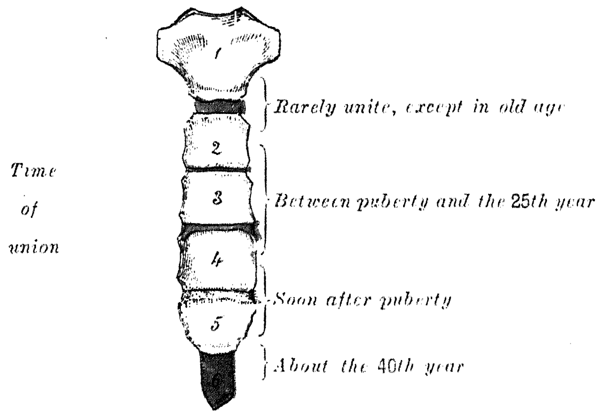


FIG. 282.



the age of forty years, but may remain ununited in old age. In advanced life the manubrium is occasionally joined to the body by bone, but when this occurs, only the peripheral part of the intervening cartilage is converted into bone; the central part remains unossified.

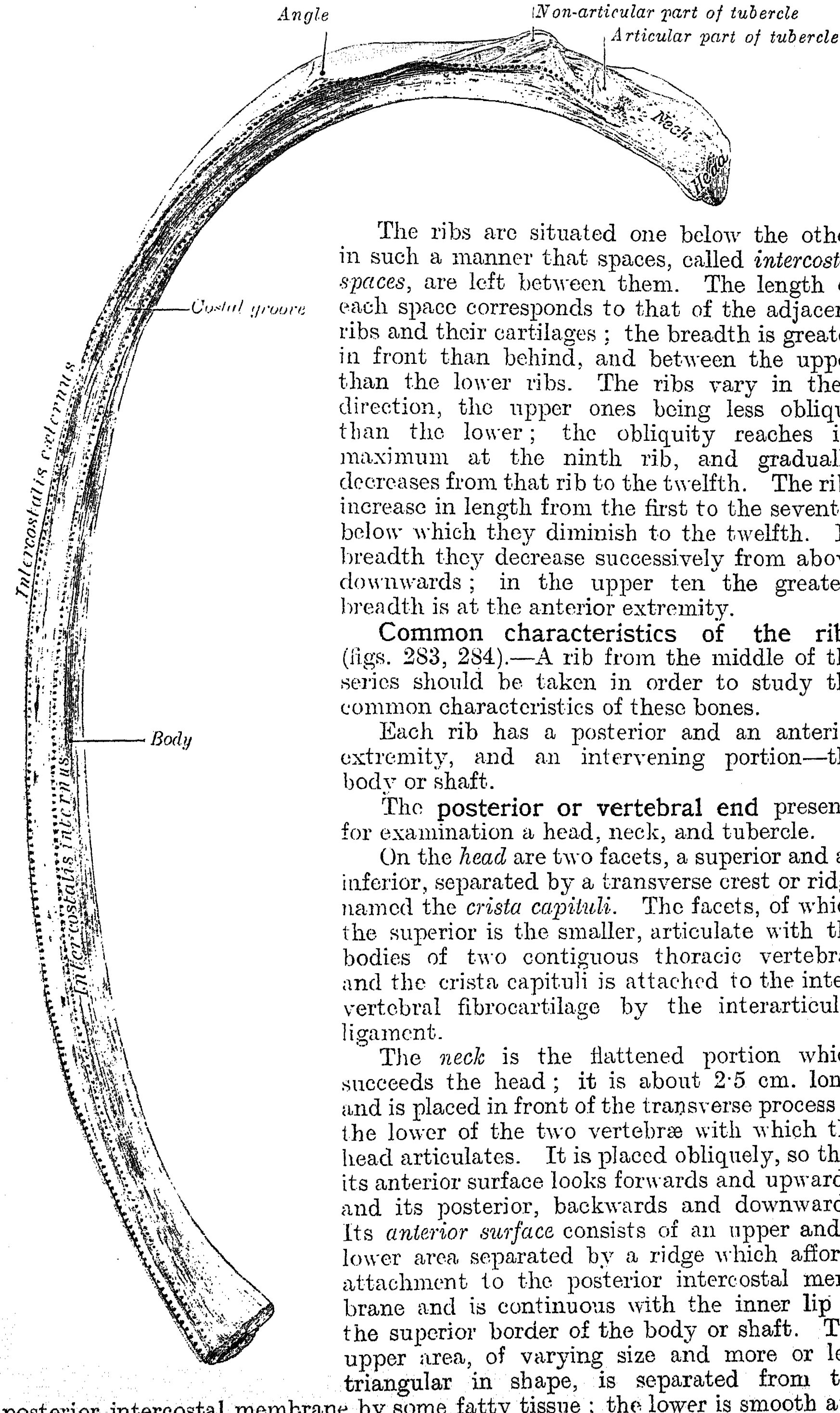
THE RIBS (COSTÆ)

The **ribs** are elastic arches of bone, which are connected behind with the vertebral column, and form a large part of the skeleton of the thorax. They are twelve in number on either side; but this number may be increased by the development of a cervical or a lumbar rib, or may be reduced to eleven. The first seven are connected in front, through the intervention of the costal cartilages, with the sternum (fig. 278); they are called *true* ribs (costæ veræ).* The remaining five are *false* ribs (costæ spuriæ); of these the cartilages of the eighth, ninth and tenth are each joined to the cartilage of the rib immediately

* Sometimes the eighth rib cartilage articulates with the sternum; this condition occurs more frequently on the right than on the left side.

above (*vertebrochondral ribs*); the eleventh and twelfth are free at their anterior ends and are termed *floating* or *vertebral* ribs.

Fig. 283.—A central rib of the left side. Inferior aspect.



The ribs are situated one below the other in such a manner that spaces, called *intercostal spaces*, are left between them. The length of each space corresponds to that of the adjacent ribs and their cartilages; the breadth is greater in front than behind, and between the upper than the lower ribs. The ribs vary in their direction, the upper ones being less oblique than the lower; the obliquity reaches its maximum at the ninth rib, and gradually decreases from that rib to the twelfth. The ribs increase in length from the first to the seventh, below which they diminish to the twelfth. In breadth they decrease successively from above downwards; in the upper ten the greatest breadth is at the anterior extremity.

Common characteristics of the ribs (figs. 283, 284).—A rib from the middle of the series should be taken in order to study the common characteristics of these bones.

Each rib has a posterior and an anterior extremity, and an intervening portion—the body or shaft.

The **posterior or vertebral end** presents for examination a head, neck, and tubercle.

On the *head* are two facets, a superior and an inferior, separated by a transverse crest or ridge named the *crista capituli*. The facets, of which the superior is the smaller, articulate with the bodies of two contiguous thoracic vertebræ, and the crista capituli is attached to the intervertebral fibrocartilage by the interarticular ligament.

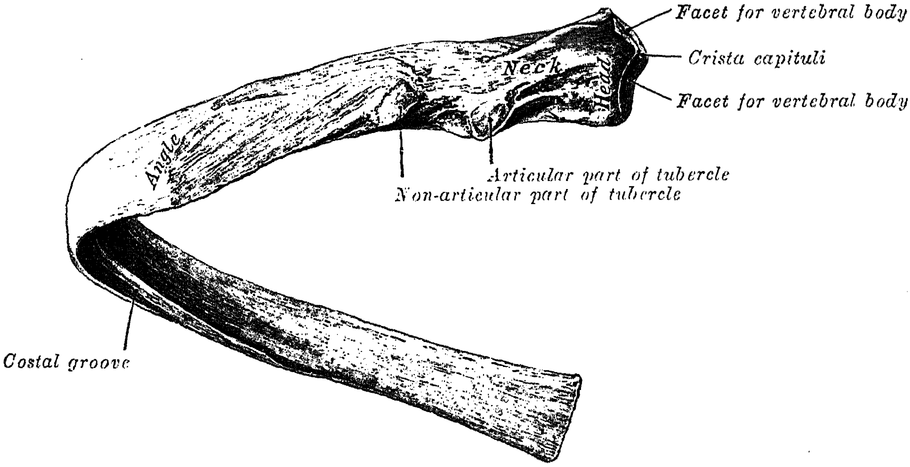
The *neck* is the flattened portion which succeeds the head; it is about 2·5 cm. long, and is placed in front of the transverse process of the lower of the two vertebræ with which the head articulates. It is placed obliquely, so that its anterior surface looks forwards and upwards, and its posterior, backwards and downwards. Its *anterior surface* consists of an upper and a lower area separated by a ridge which affords attachment to the posterior intercostal membrane and is continuous with the inner lip of the superior border of the body or shaft. The upper area, of varying size and more or less triangular in shape, is separated from the posterior intercostal membrane by some fatty tissue; the lower is smooth and covered by the costal pleura. Its *posterior surface* is rough for the attachment

of the ligament of the neck of the rib, and perforated by numerous foramina. On its *superior border* is a rough crest, the *crista colli costæ*, for the attachment of the anterior costotransverse ligament; from this crest a line can be followed into the outer lip of the superior border of the body or shaft. Its *inferior border*, more or less rounded, gives attachment to the posterior intercostal membrane and is continuous with the superior border of the costal groove.

On the posterior surface of the rib, at the junction of the neck and body, and nearer the lower than the upper border, is the *tubercle*; it is more prominent in the upper than in the lower ribs, and consists of an articular and a non-articular portion. The *articular portion*, the lower and more medial, has a small, oval surface for articulation with the end of the transverse process of the lower of the two vertebræ to which the head is connected. The *non-articular portion* is a rough elevation, and affords attachment to the ligament of the tubercle.

The **body or shaft** is thin and flat, with an external and an internal surface; and a superior and an inferior border. The *external surface* is convex, smooth, and marked, a little in front of the tubercle, by a rough line directed downwards and lateralwards; this gives attachment to one of the tendons of the Ilio-

FIG. 284.—A central rib of the left side. Posterior aspect.



costalis, and is called the *angle*. At this line the bone is bent in two directions, and at the same time twisted on its long axis. This may be demonstrated by laying a rib with its lower border in contact with a flat horizontal surface. The portion behind the angle is then seen to be inclined medialwards and upwards from the long axis of the body of the rib, while as the result of the twisting, the external surface of the part behind the angle looks downwards and that in front of the angle slightly upwards. The distance between the angle and the tubercle is progressively greater from the second to the tenth ribs. Between the angle and the tubercle the external surface is rounded, rough, and irregular, and serves for the attachment of a slip of the Longissimus dorsi. Near the sternal end of the external surface is an indistinct oblique line, the *anterior angle*. The *internal surface* is concave, smooth, directed a little upwards behind the angle, a little downwards in front of it, and is marked by a ridge which commences at the lower edge of the head; this ridge is prominent as far as the angle, but is lost at the junction of the anterior with the middle one-third of the bone. Between the ridge and the inferior border is the *costal groove*, for the intercostal vessels and nerve; within the groove are seen the orifices of numerous small foramina for nutrient vessels, which traverse the shaft obliquely from before backwards. At the posterior part of the bone the costal groove occupies the inferior border, but just in front of the angle the groove is deep and broad, and is placed on the internal surface. The upper edge of the groove serves for the attachment of an Intercostalis internus, and is continuous behind with the inferior border of the neck; the inferior

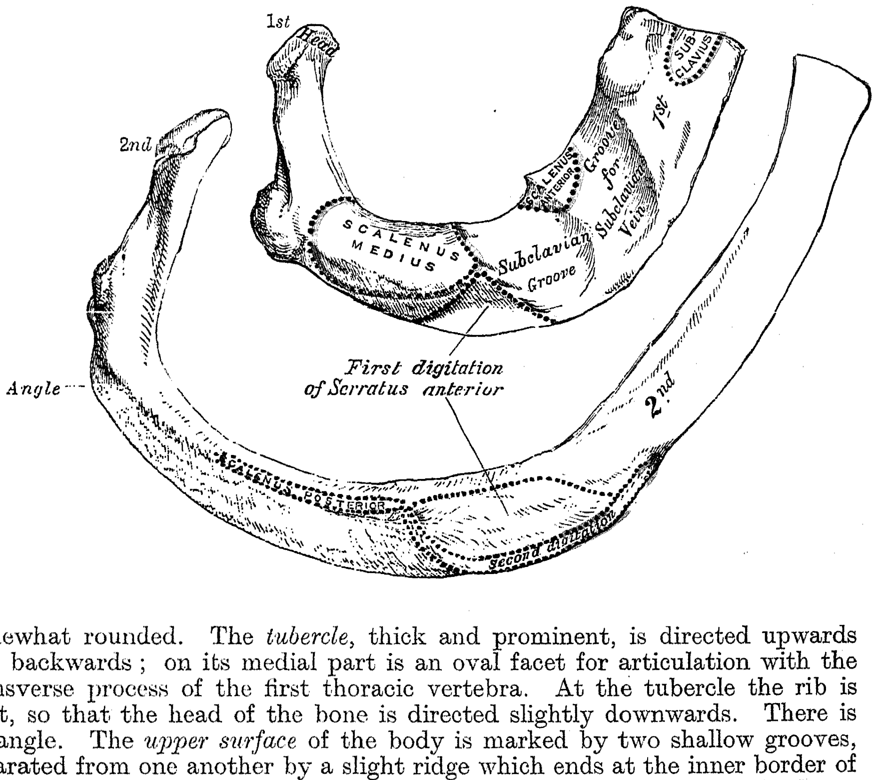
edge of the groove constitutes the *inferior border* of the rib, and gives attachment to an Intercostalis externus. The *superior border* of the rib, thick and rounded, is marked by an external and an internal lip, more distinct behind than in front; the former gives attachment to an Intercostalis externus, the latter to an Intercostalis internus.

On the **anterior or sternal end** is an oval, cup-shaped depression, into which the lateral end of the costal cartilage is received.

The first, second, tenth, eleventh, and twelfth ribs present certain variations, and require special consideration.

The **first rib** (fig. 285) is the most curved and usually the shortest of the ribs; it is broad and flat, its surfaces looking upwards and downwards, and its borders inwards and outwards. The *head* is small, rounded, and has only a single, nearly circular, articular facet, which articulates with the upper part of the side of the body of the first thoracic vertebra. The *neck* is

FIG. 285.—The first and second ribs. Superior aspect.



somewhat rounded. The *tubercle*, thick and prominent, is directed upwards and backwards; on its medial part is an oval facet for articulation with the transverse process of the first thoracic vertebra. At the tubercle the rib is bent, so that the head of the bone is directed slightly downwards. There is no angle. The *upper surface* of the body is marked by two shallow grooves, separated from one another by a slight ridge which ends at the inner border of the rib in the *scalene tubercle*. The tubercle gives the attachment of the Scalenus anterior; the groove in front of it supports the subclavian vein, that behind it the subclavian artery and the lowest trunk of the brachial plexus.* The surface in front of the anterior groove gives origin to the Subclavius muscle, and attachment to the costoclavicular ligament; behind the posterior groove is a rough area for the attachment of the Scalenus medius. The *under surface* is smooth, and destitute of a costal groove. The *outer border* is convex, thick behind, but thin in front. Immediately behind the subclavian groove it gives origin to the upper part of the first digitation of the Serratus anterior. The *inner border* is concave and thin, and marked near its centre by the scalene tubercle. The *anterior end* is larger and thicker than that of any of the other ribs.

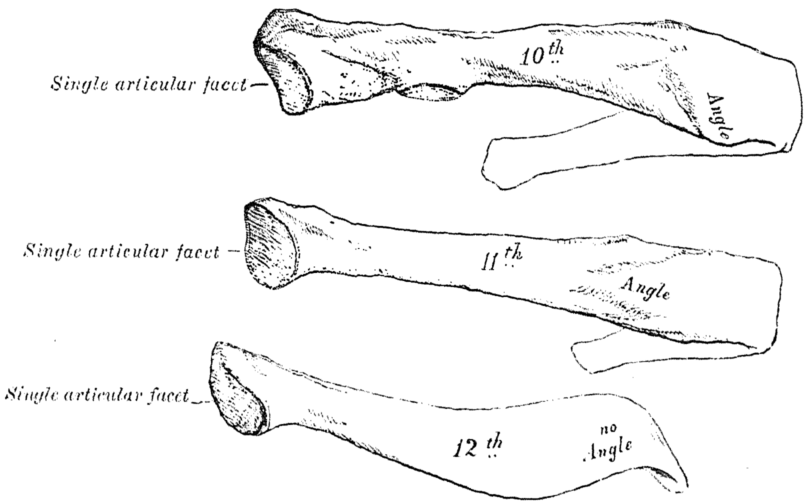
The **second rib** (fig. 285) is about twice the length of the first, but has a similar curvature. The non-articular portion of the *tubercle* is often small.

* See article by Wood Jones, *Anat. Anzeiger*, Bd. xxxvi., 1910.

The *angle* is slight, and situated close to the tubercle. The *body* is not twisted, so that both ends of it touch any plane surface upon which the rib may be laid; but at the tubercle there is an upward convexity, similar to, but smaller than, that found in the first rib. The *external surface* of the body is convex, and looks upwards and a little outwards; near its middle is a rough eminence for the origin of the lower part of the first and the whole of the second digitation of the Serratus anterior; behind and above this the Scalenus posterior is inserted. The *internal surface*, smooth and concave, is directed downwards and a little inwards; on its posterior part there is a short costal groove.

The **tenth rib** (fig. 286) has only a single articular facet on its head.

FIG. 286.—The tenth, eleventh and twelfth ribs. Posterior aspect.



The **eleventh and twelfth ribs** (fig. 286) have each a single articular facet on the head, which is of rather large size; they have no necks or tubercles, and are pointed at their anterior ends. The eleventh has a slight angle and a shallow costal groove. The twelfth has neither; it is much shorter than the eleventh, and its vertebral end is directed slightly upwards. Sometimes the twelfth rib is shorter than the first.

Structure.—The ribs consist of highly vascular spongy substance enclosed in a thin layer of compact bone.

Ossification.—Each rib, with the exception of the first and the last two, is ossified from four centres; a primary centre for the body, and three secondary centres, one for the head and one each for the articular and non-articular parts of the tubercle.* The primary centre appears near the angle, towards the end of the second month of fœtal life, and is seen first in the sixth and seventh ribs. The secondary centres for the head and tubercle appear between the sixteenth and twentieth years, and unite with the body about the twenty-fifth year. The first rib has three centres, viz.: a primary one for the body, a secondary centre for the head, and one for the tubercle. The eleventh and twelfth ribs, being destitute of tubercles, have each only two centres.

THE COSTAL CARTILAGES

The **costal cartilages** (fig. 278) are bars of hyaline cartilage which extend forwards from the anterior ends of the ribs and contribute very materially to the elasticity of the walls of the thorax. The first seven pairs are connected

* E. Fawcett states that 'in all probability there is usually no epiphysis on the non-articular part of the tuberosity below the sixth or seventh rib' (*Journal of Anatomy and Physiology*, vol. xlv.).

with the sternum; the eighth, ninth, and tenth are each articulated with the lower border of the cartilage immediately above; the last two have pointed extremities which end in the wall of the abdomen. The costal cartilages vary in their length, breadth, and direction. They increase in length from the first to the seventh, then gradually decrease to the twelfth. They diminish in breadth from the first to the last, and so also do the intervals between them. They are broad at their attachments to the ribs, and taper towards their medial extremities, with the exception of the first and second which are of the same breadth throughout, and the sixth, seventh, and eighth which are enlarged where their margins are in contact. The first cartilage descends a little, the second is horizontal, the third ascends slightly, while the others are angular, following the course of the ribs for a short distance, and then ascending to the sternum or preceding cartilage.

Each costal cartilage has two surfaces, two borders, and two ends. The *anterior surface* is convex, and looks forwards and upwards: that of the first gives attachment to the costoclavicular ligament and the Subclavius muscle; those of the first six or seven at their medial ends, to the Pectoralis major. The others are covered by, and give partial attachment to, some of the flat muscles of the abdomen. The *posterior surface* is concave, and directed backwards and downwards; that of the first gives attachment to the Sternothyreoideus, those of the second to the sixth inclusive to the Transversus thoracis, and the six inferior ones to the Transversus abdominis and the Diaphragm. The *superior border* is concave, and the *inferior* convex; they afford attachment to the Intercostales interni. The inferior borders of the sixth, seventh, eighth, and ninth cartilages present heel-like projections at the points of greatest convexity; a similar heel-like projection occurs on the lower border of the fifth right cartilage in 72 per cent. and on the fifth left cartilage in 50 per cent. (Fawcett). On these projections are oblong facets which articulate respectively with facets on slight projections from the superior borders of the sixth, seventh, eighth, ninth, and tenth cartilages. The *lateral end* of each cartilage is continuous with the osseous tissue of the rib to which it belongs. The *medial end* of the first is continuous with the sternum; the medial ends of the six succeeding ones are rounded and articulate with shallow concavities on the lateral margins of the sternum. The medial ends of the eighth, ninth, and tenth costal cartilages are pointed, and each is connected with the cartilage immediately above. Those of the eleventh and twelfth are pointed and free.

In old age the costal cartilages are prone to undergo superficial ossification.

THE THORAX

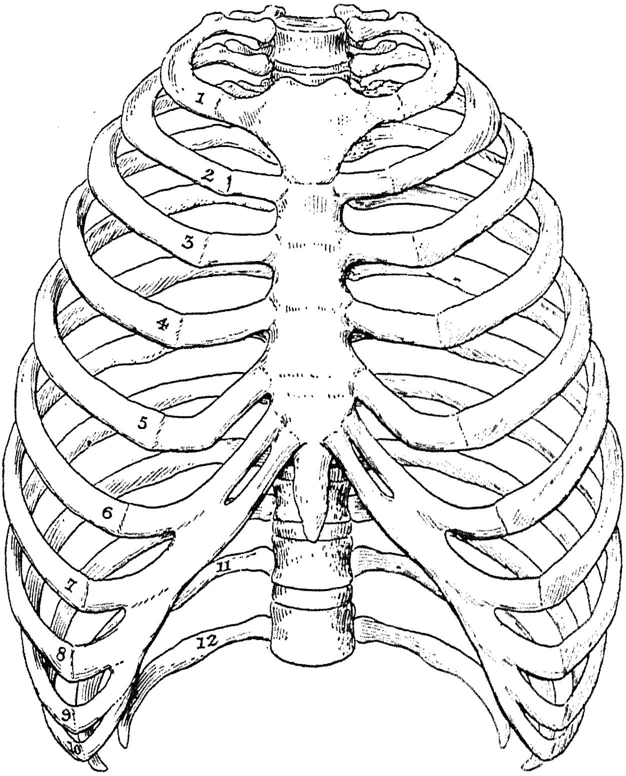
The skeleton of the **thorax**, or **chest** (fig. 287), is an osseocartilaginous cage which contains and protects the principal organs of respiration and circulation. It is conical in shape, narrow above and broad below, flattened from before backwards, and longer behind than in front. It is reniform on horizontal section on account of the forward projection of the vertebral bodies.

Boundaries.—*Posteriorly* it is formed by the twelve thoracic vertebræ and the posterior parts of the ribs. On either side of the vertebral column is a deep groove in consequence of the lateral and backward direction which the ribs take from their vertebral extremities to their angles. *Anteriorly* it is formed by the sternum and costal cartilages, and this surface is flattened or slightly convex. *Laterally* it is convex, and is formed by the ribs. The ribs and costal cartilages are separated from each other by the intercostal spaces, eleven in number, which are occupied by the Intercostal muscles and membranes.

The *upper opening* of the thorax is reniform in shape; its anteroposterior diameter is about 5 cm., its transverse about 10 cm. It slopes downwards and forwards, and is bounded by the first thoracic vertebra behind, the superior border of the manubrium sterni in front, and the first rib on either side. The *lower opening* is bounded by the twelfth thoracic vertebra behind, by the

eleventh and twelfth ribs at the sides, and in front by the cartilages of the tenth, ninth, eighth, and seventh ribs, which ascend on either side and form an angle, the *subcostal angle*, into the apex of which the xiphoid process projects. The lower opening is wider transversely than from before backwards, and slopes obliquely downwards and backwards; it is closed by the Diaphragm which forms the floor of the thorax.

FIG. 287.—The skeleton of the thorax. Anterior aspect.



The thorax of the female differs from that of the male as follows: 1. Its capacity is less. 2. The sternum is shorter. 3. The upper margin of the sternum is on a level with the lower part of the body of the third thoracic vertebra, whereas in the male it is on a level with the lower part of the body of the second. 4. The upper ribs are more movable, and so allow a greater expansion of the upper part of the thorax.

Applied Anatomy.—Fracture of the sternum is by no means common, owing, no doubt, to the elasticity of the ribs and their cartilages, which support it like so many springs. The fracture usually occurs in the upper half of the body. Dislocation of the body from the manubrium may take place, and is sometimes described as a fracture.

The ribs are frequently broken, though from their connexions and shape they are able to withstand great force, yielding under the injury and recovering themselves like a spring. The middle ribs are the most liable to fracture. The first, and to a less extent the second, being protected by the clavicle, are rarely fractured; and the eleventh and twelfth on account of their loose and floating condition enjoy a like immunity. The fracture generally occurs from indirect violence from forcible compression of the chest walls, and the bone then gives way at its weakest part, i.e. just in front of the angle. But the ribs may also be broken by direct violence, in which case the bone is driven inwards at the point struck. Fracture of the ribs is frequently complicated with some injury to the viscera contained within the thorax or upper part of the abdominal cavity; this is most likely to occur in fractures from direct violence.

Fracture of the costal cartilages, or separation of the cartilages from the ribs, may also

take place, though they are comparatively rare injuries. In workmen the pressure of tools may displace the xiphoid process inwards.

The ribs are frequently the seat of tuberculous disease, with the formation of a chronic abscess in the chest-wall. This may not immediately overlie the carious portion of rib, as the pus is often directed a considerable distance along the costal groove before appearing beneath the integument.

Resection of a portion of a rib is often required in order to give efficient drainage to an empyema; this is referred to in the description of the respiratory organs.

Cervical ribs derived from the seventh cervical vetebra (page 169) are of not infrequent occurrence, and are important clinically because they may give rise to nervous or vascular symptoms. The cervical rib may be a mere epiphysis articulating only with the transverse process of the vertebra, but more commonly it consists of a defined head, neck and tubercle, with or without a body. It extends lateralwards, or forwards and lateralwards, into the posterior triangle of the neck, where it may terminate in a free end or may join the first thoracic rib, the first costal cartilage, or the sternum.* It varies much in shape, size, direction, and mobility. If it reach far enough forwards, its relations are similar to those of the first thoracic rib; part of the brachial plexus and the subclavian artery and vein cross over it, and are apt to suffer compression in so doing. Pressure on the artery may obstruct the circulation so much that arterial thrombosis results, causing gangrene of the finger-tips. Pressure on the nerves is commoner, and affects the eighth cervical and first thoracic nerves, causing paralysis of the muscles they supply, and neuralgic pains, trophic changes and paræsthesia in the area of skin to which they are distributed: no oculopupillary changes are to be found. If these symptoms be severe, removal of the rib or as much of it as causes pressure on the vessels and nerves is called for. The operation is not free from difficulty, and has been followed by paralysis of the muscles and by subclavian aneurysm, due to injuries inflicted in the course of the operation.

The *thorax* is frequently found to be altered in shape in certain diseases.

In *rickets*, the ends of the ribs, where they join the costal cartilages, become enlarged, giving rise to the so-called 'rickety rosary,' which in mild cases is only found on the internal surface of the thorax. Lateral to these enlargements the softened ribs sink in, so as to present a groove passing downwards and lateralwards on either side of the sternum. The ribs affected are the second to the eighth, the lower ones being prevented from falling in by the presence of the liver, stomach, and spleen; and when the abdomen is distended, as it often is in rickets, the lower ribs may be pushed outwards, causing a transverse groove (Harrison's sulcus) just above the costal arch. The sternum is forced forwards by the bending of the ribs, and the anteroposterior diameter of the thorax is increased; this deformity, often asymmetrical, is known as *pigeon breast*. In many instances it is associated in children with obstruction in the upper air-passages, due to enlarged tonsils or adenoid growths. In some rickety children or adults, and also in others who give no history or further evidence of having had rickets, an opposite condition obtains. The lower part of the sternum and often the xiphoid process as well are deeply depressed backwards, producing an oval hollow in the lower sternal and upper epigastric regions; this is known as 'funnel-breast.' The *phthisical chest* is often long and narrow, with great obliquity of the ribs and projection of the scapulæ. In *pulmonary emphysema* the chest is enlarged in all its diameters, and presents on section an almost circular outline. It has received the name of the 'barrel-shaped chest.' In severe cases of *lateral curvature of the vertebral column* the thorax becomes much distorted. In consequence of the rotation of the bodies of the vertebræ which takes place in this disease, the ribs opposite the convexity of the dorsal curve become extremely convex behind, being thrown out and bulging, and at the same time flattened in front, so that the two ends of the same rib are almost parallel. Coincidently with this the ribs on the opposite side, on the concavity of the curve, are sunk and depressed behind, and bulging and convex in front.

More or less shrinkage of one side of the thorax is often seen as a consequence of adhesive pleurisy, in which the pulmonary and parietal pleuræ adhere closely to one another and the lung becomes collapsed and fibrosed. If this process be at all complete, great deformity of the chest results, the ribs on the affected side falling in, together with obliteration of the intercostal spaces; the contents of the mediastinal cavity are pulled over towards the affected side, and the other lung becomes emphysematous compensatorily. The vertebral column becomes scoliotic, with the concavity of the curve towards the affected side.

THE SKULL

The skull is supported on the top of the vertebral column, and is of an ovoid shape, wider behind than in front. It is composed of a series of flattened or irregular bones which, with the exception of the mandible, are immovably jointed together. It is divisible into: (1) the *cranium*, which consists of

* W. Thorburn, *The Med. Chronicle*, Manchester, 4th series, xiv. 1907.

fifteen bones, and (2) the *skeleton of the face*, which consists of seven, as follows :

Skull, 22 bones	*Cranium*, 15 bones	Occipital. Sphenoidal. Two Temporals. Two Parietals. Frontal. Ethmoidal. Two Inferior Nasal Conchæ. Two Lacrimals. Two Nasals. Vomer.
	Face, 7 bones	Two Maxillæ. Two Palatines. Two Zygomatics. Mandible.

The hyoid bone, situated at the root of the tongue and attached to the base of the skull by ligaments, is described in this section.

THE CRANIAL BONES (OSSA CRANII)

The Occipital Bone (Os Occipitale)

The **occipital bone** (figs. 288, 289), situated at the posterior and inferior part of the cranium, is trapezoid in shape and concave forwards. It is pierced by a large oval aperture, the *foramen magnum*, through which the cranial cavity communicates with the vertebral canal. The expanded plate above and behind this foramen is named the *squama* ; the thick, somewhat quadrilateral piece in front of it is called the *basilar part* ; whilst on either side of it is the *lateral portion*.

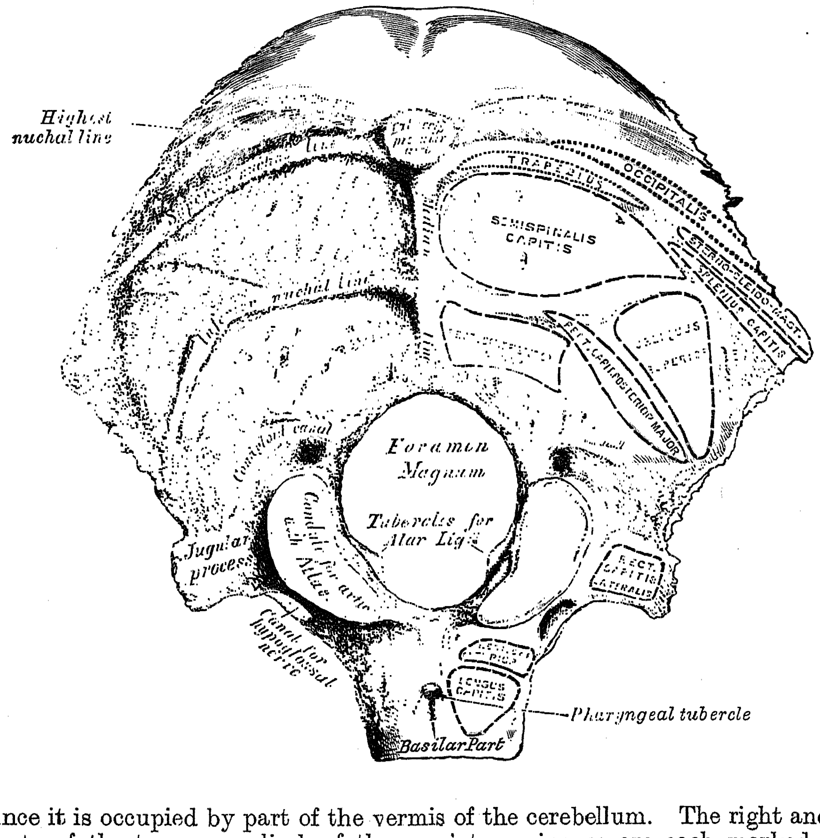
The **squama** of the occipital bone, situated above and behind the foramen magnum, is curved from above downwards and from side to side.

The *external surface* of the squama is convex and presents midway between the summit of the bone and the foramen magnum a prominence, the *external occipital protuberance*. Extending lateralwards from this on either side are two curved lines, one a little above the other. The upper line, often faintly marked, is named the *highest nuchal line* (linea nuchæ suprema), and to it the galea aponeurotica (epicranial aponeurosis) is attached. The lower line is termed the *superior nuchal line*. The part of the external surface above the highest nuchal lines is named the *planum occipitale* ; it is smooth, and covered with the Occipitalis muscle. The part below the highest nuchal line is termed the *planum nuchale*, and is rough and irregular for the attachment of several muscles. From the external occipital protuberance a ridge, the *median nuchal line*, often faintly marked, descends to the foramen magnum, and affords attachment to the ligamentum nuchæ ; running lateralwards from the middle of this line on either side is the *inferior nuchal line*. Several muscles (fig. 288) are attached to the outer surface of the squama, thus : the superior nuchal line gives origin to the Occipitalis and Trapezius, and insertion to the Sternocleidomastoideus and Splenius capitis ; into the surface between the superior and inferior nuchal lines the Semispinalis capitis and the Obliquus capitis superior are inserted ; the inferior nuchal line and the area below it receive the insertions of the Recti capitis posteriores major and minor. The posterior atlanto-occipital membrane is attached around the posterolateral part of the foramen magnum, just outside the margin of the foramen.

The *internal surface* of the squama is deeply concave and divided into four fossæ by a *cruciate eminence*, one limb of which is in the median sagittal plane, the other transverse. The upper two fossæ are triangular, and lodge the posterior parts of the occipital lobes of the cerebrum ; the lower two are quadrilateral and support the hemispheres of the cerebellum. At the point

of intersection of the limbs of the cruciate eminence is the *internal occipital protuberance.* The upper division of the sagittal limb of the cruciate eminence runs from this protuberance to the superior angle of the bone, and on one side of it (generally the right) is a wide groove, the *sagittal sulcus*, which lodges the hinder part of the superior sagittal sinus ; to the margins of this sulcus the posterior part of the falx cerebri is attached. The lower division of the sagittal limb of the cruciate eminence is prominent, and is named the *internal occipital crest* ; it gives attachment to the falx cerebelli, and bifurcates near the foramen magnum ; in the attached margin of this falx is the occipital sinus, which is sometimes duplicated. At the lower part of the internal occipital crest, a small depression is sometimes distinguishable ; it is termed the *vermian fossa*,

Fig. 288.—The occipital bone. External aspect.



since it is occupied by part of the vermis of the cerebellum. The right and left parts of the transverse limb of the cruciate eminence are each marked by a *transverse sulcus*, which extends lateralwards from the internal occipital protuberance ; these sulci accommodate the transverse sinuses, and their margins give attachment to the tentorium cerebelli. The right transverse sulcus is usually larger than the left, and continuous with the sagittal sulcus ; but the left may be larger than the right, or the two may be almost equal in size. The angle of union of the superior sagittal and transverse sinuses is named the *confluence of the sinuses* or *torcular Herophili*,* and its position is indicated by a depression on one or other side of the protuberance.

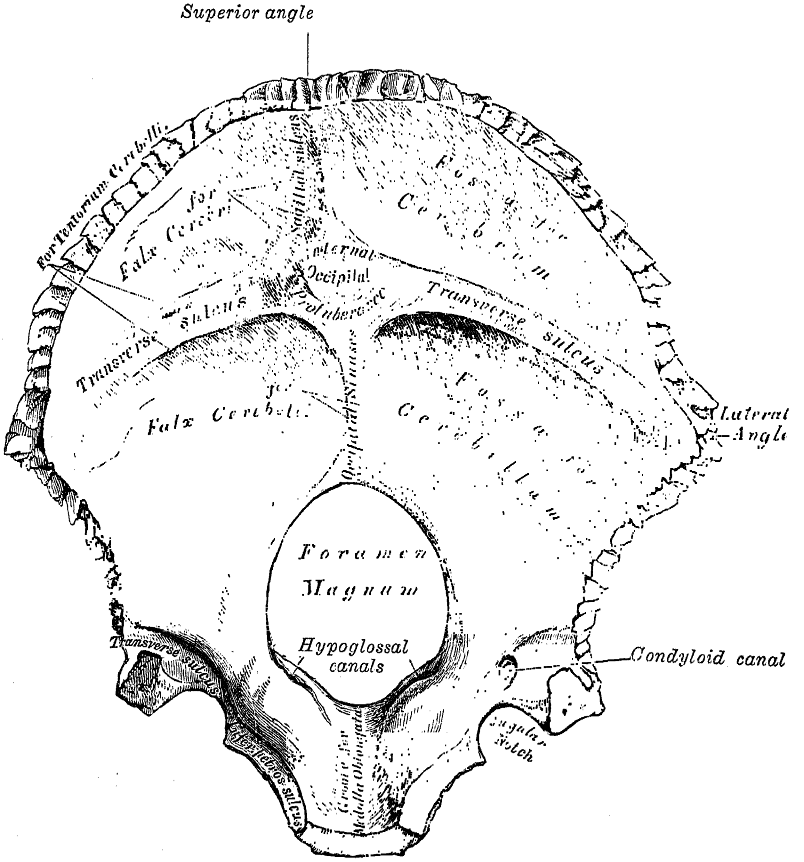
The *superior angle* of the squama articulates with the occipital angles of the parietal bones, and, in the fœtal skull, corresponds in position with the *occipital fonticulus* (posterior fontanelle). The *lateral angles* are at the ends of the transverse sulci ; each is received into the interval between the mastoid angle of the parietal bone and the mastoid part of the temporal bone. The

* The columns of blood coming in different directions were supposed to be pressed together at this point (*torcular*, a wine-press).

lambdoid or superior borders extend from the superior to the lateral angles; they are serrated for articulation with the occipital borders of the parietal bones, and form by this union the lambdoid suture. The *mastoid or inferior borders* extend from the lateral angles to the jugular processes; each articulates with the mastoid process of the corresponding temporal bone.

The **basilar part** of the occipital bone extends forwards and upwards from the foramen magnum, and presents *in front* a more or less quadrilateral surface. In the young skull this surface is rough and uneven, and is joined

FIG. 289.—The occipital bone. Internal aspect.



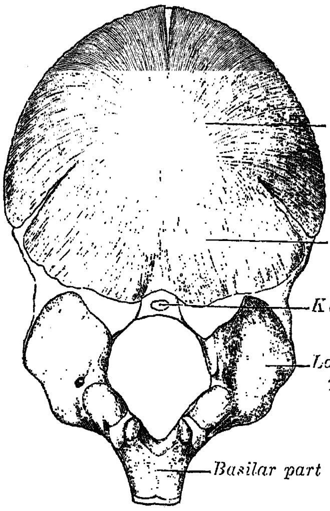
to the body of the sphenoidal bone by a plate of cartilage. By the twenty-fifth year this plate of cartilage has undergone ossification, and the occipital and sphenoidal bones are fused.

On the *inferior surface* of the basilar part, about 1 cm. in front of the foramen magnum, is the *pharyngeal tubercle* which gives attachment to the fibrous raphe of the pharynx. On either side of the middle line the Longus capitis and Rectus capitis anterior are inserted, and immediately in front of the foramen magnum the anterior atlanto-occipital membrane is attached.

The *superior surface* of the basilar part consists of a broad, shallow groove which inclines upwards and forwards from the anterior border of the foramen magnum; it supports the medulla oblongata and the lower part of the pons, and near the margin of the foramen gives attachment to the membrana tectoria. On the lateral margins of this surface are the *inferior petrosal sulci* for the inferior petrosal sinuses, and below each of these sulci the lateral margin of the basilar part is rough for articulation with the petrous part of the temporal bone.

The **lateral parts** of the occipital bone are situated at the sides of the foramen magnum; on their *inferior surfaces* are two oval processes, the *occipital condyles*, for articulation with the superior facets of the atlas or first cervical vertebra. The condyles are oval or reniform in shape, with their long axes running forwards and medialwards, so that their anterior ends are closer together than their posterior, and encroach on the basilar portion of the bone; the posterior ends extend back to the level of the middle of the foramen magnum. The articular surfaces of the condyles are convex from before backwards and from side to side; they look downwards and lateralwards, and are occasionally constricted near their centres. On the medial side of either is a rough impression or tubercle for the alar ligament. Above the anterior part of either condyle is the *hypoglossal canal* (anterior condyloid foramen); this canal begins on the cranial surface of the bone a short distance above the anterior part of the foramen magnum, and is directed lateralwards and forwards. It may be partially or completely divided into two by a spicule of bone; it gives exit to the hypoglossal nerve, and entrance to a meningeal branch of the ascending pharyngeal artery. Behind either condyle is a depression, the *condyloid fossa*, which receives the posterior margin of the corresponding superior facet of the atlas when the head is bent backwards; the floor of this fossa is sometimes perforated by the *condyloid canal*, through which an emissary vein passes from the transverse sinus. Extending lateralwards from the posterior half of the condyle is the *jugular process*, a quadrilateral plate of bone, indented in front by the *jugular notch* which, in the articulated skull, forms the posterior part of the jugular foramen. The jugular notch is sometimes divided into two by a bony spicule, the *intrajugular process*, which projects forwards and lateralwards. The under surface of the jugular process is rough, and gives attachment to the Rectus capitis lateralis; from this surface an eminence, the *paramastoid process*, sometimes projects downwards, and may be of sufficient length to articulate with the transverse process of the atlas. Laterally the jugular process presents a rough quadrilateral or triangular area which is joined to the jugular surface of the temporal bone by a plate of cartilage; after the age of twenty-five this plate tends to ossify.

FIG. 290.—The occipital bone at birth. External aspect.



On the *superior surface* of the lateral part is an oval eminence, the *tuberculum jugulare*, which overlies the hypoglossal canal; behind this tubercle is a shallow furrow for the glossopharyngeal, vagus, and accessory nerves. On the superior surface of the jugular process is a deep groove which curves medialwards and forwards around an upwardly directed hook shaped process, and ends at the jugular notch. This groove lodges the terminal part of the transverse sinus, and, close to the medial margin of the groove, the condyloid canal opens.

The *foramen magnum* is a large oval aperture with its long diameter in the median sagittal plane. The foramen is wider behind than in front, where it is encroached upon by the occipital condyles. It transmits the medulla oblongata and its membranes, the spinal portions of the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, the membrana tectoria, and the alar ligaments.

Structure.—The occipital, like the other cranial bones, consists of two compact lamellæ, called the *outer and inner tables*, between which is the spongy substance or *diploë*; the bone is thick at the ridges, protuberances and condyles, and at the anterior portion of the basilar part; in the lower parts of the inferior fossæ it is thin, semitransparent, and destitute of diploë.

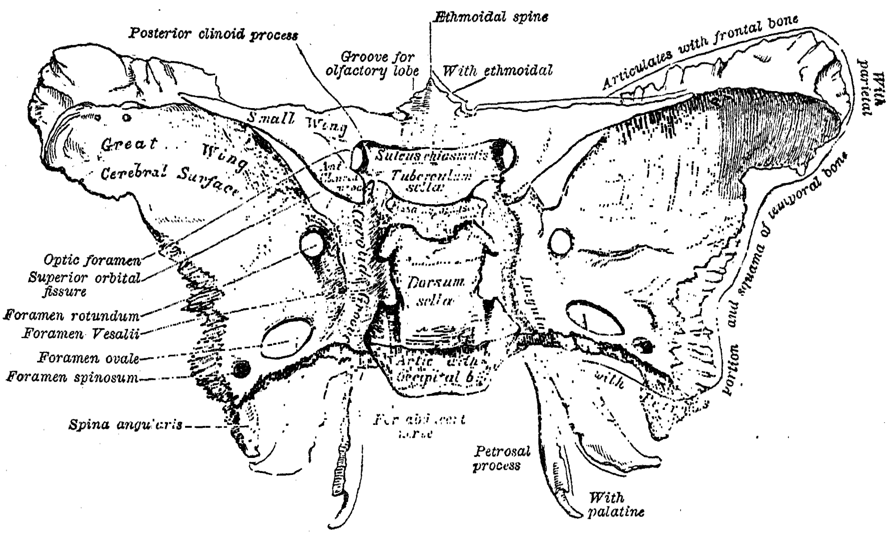
Ossification (fig. 290).—The part of the squama above the highest nuchal line

is developed in membrane, and is ossified from two centres,* one appearing on either side of the middle line about the second month of fœtal life; this part of the squama may remain separate throughout life, and is then known as the *interparietal bone.* The rest of the occipital bone is developed in cartilage. The lower part of the squama is ossified from two centres, which appear about the seventh week of fœtal life and soon unite to form a single piece. Union of the upper and lower portions of the squama takes place in the third month of fœtal life. An occasional centre appears in the posterior margin of the foramen magnum about the sixteenth week (Kerckring); it unites with the rest of the squama before birth. Each of the lateral parts ossifies from a single centre which appears during the eighth week of fœtal life. The basilar portion is ossified from one centre,* which appears about the sixth week of fœtal life. About the fourth year the squama unites with the lateral portions, and about the sixth year the bone consists of a single piece. Between the eighteenth and twenty-fifth years the occipital and sphenoidal bones unite to form a single bone.

The Sphenoidal Bone (Os Sphenoidale)

The **sphenoidal body** (figs. 291 to 293) is situated at the base of the skull, in front of the temporal bones and the basilar part of the occipital bone.

Fig. 291.—The sphenoidal bone. Superior aspect.



It somewhat resembles a bat with wings extended, and consists of a central portion or body, two great and two small wings extending lateralwards from the sides of the body, and two pterygoid processes which are directed downwards from the adjoining parts of the body and great wings.

The **body** of the sphenoidal bone, more or less cubical in shape, contains two large cavities, the *sphenoidal air-sinuses*, separated from each other by a septum.

The *cerebral or superior surface* of the body (fig. 291) presents in front the *ethmoidal spine*, for articulation with the lamina cribrosa of the ethmoidal bone; behind this is a smooth surface, which is faintly grooved on either side of the middle line for the olfactory tracts of the brain. The superior surface is bounded behind by a ridge, which forms the anterior border of a transverse groove, the *sulcus chiasmatis* (optic groove); this sulcus ends on either side in the *optic foramen.* Posterior to the sulcus is a more or less oval elevation, the *tuberculum sellæ*; and behind this is a deep depression, the *sella turcica*, the deepest part of which lodges the hypophysis cerebri and is known as the *fossa hypophyseos.* The anterior boundary of the sella turcica is completed

* Mall, *American Journal of Anatomy*, vol. v. 1906.

backwards and medialwards ; those on the inferior are convex, and are directed forwards and lateralwards. The inferior articular processes are closer together than the superior, and, in the articulated vertebral column, are embraced by the superior processes of the subjacent vertebra. The *transverse processes* are situated in front of the articular processes instead of behind them as in the thoracic vertebræ, and are homologous with the ribs. Those of the upper three vertebræ arise from the junctions of the pedicles and laminæ, and are long, slender, and horizontally directed ; those of the lower two vertebræ incline a little upwards, and spring from the pedicles and posterior parts of the bodies. The transverse process of the first lumbar vertebra is sometimes developed as a separate piece which may remain ununited with the rest of the bone, thus forming a lumbar rib. Of the tubercles noticed in connexion with the transverse processes of the lower thoracic vertebræ, the *superior* is connected in the lumbar region with the posterior part of the superior articular process, and is named the *mamillary process ;* the *inferior* is situated at the posterior part of the base of the transverse process, and is called the *accessory process* (fig. 257).*

The **fifth lumbar vertebra** (fig. 258) is characterised by its body being considerably deeper in front than behind, a condition which accords with the prominence of the sacrovertebral articulation ; by the small size of its spinous process ; by the wide interval between the inferior articular processes ; and by the thickness of its transverse processes, which spring from the body as well as from the pedicles.

The Sacrum (Os Sacrum)

The **sacrum** is a large, wedge-shaped bone formed by the fusion of the five sacral vertebræ. It is situated at the upper and posterior part of the pelvic cavity, where it is inserted like a wedge between the two hip-bones. Its base projects upwards and forwards to articulate with the fifth lumbar vertebra and form with it the prominent *sacrovertebral angle* ; its apex articulates with the coccyx. The bone is placed very obliquely and is curved longitudinally with a dorsal convexity, so that its central part is projected upwards and backwards to give increased capacity to the cavity of the lesser pelvis. The sides of the wedge are somewhat sinuous in outline since the third sacral vertebra is rather wider than the second. The sacrum has a pelvic, a dorsal, and two lateral surfaces, a base, an apex, and a central canal.

The *pelvic surface* of the sacrum (fig. 259) is concave from above downwards, and slightly so from side to side. It is crossed transversely by four ridges, which correspond in position with the original planes of separation between the five segments of the bone : the portions separated by the ridges are the bodies of the sacral vertebræ. The body of the first vertebra is of large size, and in form resembles that of a lumbar vertebra ; the succeeding ones diminish from above downwards, are flattened from before backwards, and curved to accommodate themselves to the form of the sacrum, being concave in front, and convex behind. On either side, at the ends of the ridges are the four *anterior sacral foramina*, somewhat rounded in form, diminishing successively in size from above downwards, and directed lateralwards and forwards : they open from the sacral canal and give exit to the anterior divisions of the sacral nerves, and entrance to the lateral sacral arteries. On either side of these foramina are the *lateral parts* of the sacrum, each consisting of five separate segments at an early period of life ; in the adult, these are blended with the bodies and with each other. Each lateral part is traversed by four broad, shallow grooves, for the anterior divisions of the sacral nerves; the grooves are separated from one another by prominent ridges which give origin to the Piriformis.

In a medial sagittal section of the sacrum (fig. 263) the central parts of the bodies of the sacral vertebræ are seen to be separated by intervals which,

* The mamillary and accessory processes 'are merely muscular processes which, represented and conjoined in the thoracic region, become separated in the lumbar region by the passage of the internal branch of the posterior division of the lower thoracic and lumbar nerves between them.' (Wood Jones, *Journal of Anatomy and Physiology*, vol. xlvii., p. 118.)

laminæ. A lateral recess may extend from one or other sinus into the great wing and lingula ;* the sinuses occasionally reach into the basilar part of the occipital bone nearly as far as the foramen magnum. In the articulated skull they are closed, in front and below, by the *sphenoidal conchæ* (p. 205), only a round opening being left in the anterior wall of each sinus by which it communicates with the spheno-ethmoidal recess at the upper and posterior part of the nasal cavity, and occasionally with the posterior ethmoidal air-sinuses. Each half of the anterior surface of the body of the sphenoidal bone consists of two parts : (*a*) an upper and lateral depressed area which completes, with the labyrinth of the ethmoidal bone, the posterior ethmoidal air-sinuses ; its lateral margin articulates with the lamina papyracea of the ethmoidal bone above, and with the orbital process of the palatine bone below ; (*b*) a lower and medial, smooth, triangular area which forms the posterior part of the roof of the nose ; near its superior angle is the round orifice leading from the sphenoidal sinus.

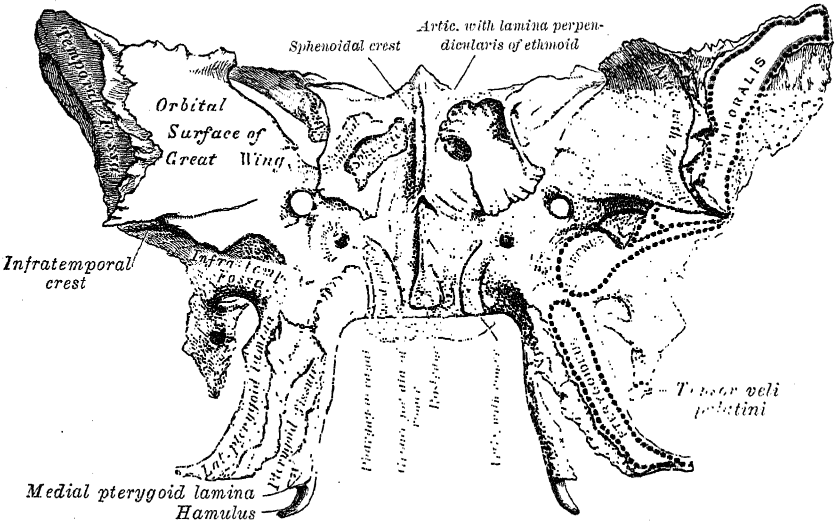


FIG. 293.—The sphenoidal bone. Antero-inferior aspect.

The *inferior surface* of the body (fig. 293) presents, in the middle line, a triangular spine, the *sphenoidal rostrum*, which, in the articulated skull, projects into a deep fissure between the anterior parts of the alæ of the vomer. The posterior, triangular parts of the sphenoidal conchæ extend backwards on the sides of the rostrum, and articulate with the alæ of the vomer. On either side of the posterior part of the rostrum, and immediately behind the apex of the sphenoidal concha, is a projecting lamina, the *vaginal process*, directed medialwards from the base of the medial pterygoid lamina, with which it will be described.

The **great wings** (alæ magnæ) of the sphenoidal bone are two strong processes, which curve upwards and lateralwards from the sides of the body. The posterior part of each is triangular and fits into the angle between the petrous portion and the squama of the temporal bone ; projecting downwards from the apex of this triangular portion is a pointed process named the *spina angularis*, on the medial side of which there is usually a groove, directed downwards and forwards, for the chorda tympani nerve.† To the spina angularis are attached the sphenomandibular ligament and a part of the Tensor veli palatini.

* V. Z. Cope (*Journal of Anatomy and Physiology*, vol. li. part ii.) found a well-marked lateral recess in 72 out of 292 sinuses examined, and pointed out that the hypophysis, the anterior part of the internal carotid artery, the optic and maxillary nerves, and the nerve of the pterygoid canal may give rise to elevations in the walls of the sinuses.

† R. Clements Lucas, *Proceedings of the Anatomical Society of Great Britain and Ireland*, November, 1894.

The *cerebral or superior surface* of the great wing (fig. 291) forms part of the floor of the middle fossa of the skull; it is deeply concave and presents depressions corresponding with the convolutions of the anterior part of the temporal lobe of the brain. At its anteromedial part is a circular aperture, the *foramen rotundum*, for the passage of the maxillary nerve. Behind and lateral to this foramen is the *foramen ovale*, for the transmission of the mandibular nerve, the accessory meningeal artery, and sometimes the lesser superficial petrosal nerve.* Medial to the foramen ovale, a small aperture, the *foramen Vesalii*, is often seen; when present it opens below at the lateral side of the scaphoid fossa, and transmits a small vein from the cavernous sinus. In the posterior angle, near to but in front of the spina angularis, is a short canal, the *foramen spinosum*, which transmits the middle meningeal artery and the nervus spinosus.

The *lateral surface* of the great wing (fig. 293) is convex from above downwards, and is divided by a transverse ridge, the *infratemporal crest*, into an upper or temporal and a lower or infratemporal surface. The *temporal surface*, concave from before backwards, forms a portion of the temporal fossa, and gives origin to a part of the Temporalis. The *infratemporal surface* is concave and directed downwards; it forms a part of the infratemporal fossa, and, together with the infratemporal crest, gives origin to the upper head of the Pterygoideus externus. It is pierced by the foramen ovale and foramen spinosum, and at its posterior part is the spina angularis. Medial to the anterior extremity of the infratemporal crest is a triangular process which serves to increase the attachment of the Pterygoideus externus. A ridge runs downwards and medialwards from this triangular process to the front of the lateral pterygoid lamina; it forms the anterior limit of the infratemporal surface, and, in the articulated skull, the posterior boundary of the pterygomaxillary fissure.

The *orbital surface* of the great wing (fig. 293), quadrilateral in shape, is directed forwards and medialwards and forms the posterior part of the lateral wall of the orbit. Its upper serrated edge articulates with the orbital plate of the frontal bone; its lateral serrated margin with the zygomatic bone. Its inferior smooth border forms the posterolateral boundary of the inferior orbital fissure. Its medial sharp margin constitutes the lower boundary of the superior orbital fissure; projecting from near the centre of this margin is a small tubercle which gives an attachment to part of the Rectus lateralis oculi. Below the medial end of the superior orbital fissure is a grooved surface, which forms the posterior wall of the pterygopalatine fossa, and is pierced by the foramen rotundum.

The margin of the great wing (fig. 291).—The portion of the margin of the great wing which extends from the body to the spina angularis is irregular. Its medial half forms the anterior boundary of the *foramen lacerum*, and presents the posterior aperture of the pterygoid canal for the passage of the corresponding nerve and artery. Its lateral half articulates, by means of a synchondrosis, with the petrous portion of the temporal bone, and between the two bones, on the under surface of the skull, is a furrow, the *sulcus tubæ*, for the lodgment of the cartilaginous part of the auditory tube. Extending forwards from the spina angularis is the *squamosal margin*, a concave, serrated edge, bevelled at the expense of the inner surface below, and of the outer surface above, for articulation with the temporal squama. The tip of the great wing, or *parietal angle*, is bevelled at the expense of the inner surface, and articulates with the sphenoidal angle of the parietal bone. Medial to this is a triangular rough area, for articulation with the frontal bone; the medial angle of this area is continuous with the sharp edge which forms the lower boundary of the superior orbital fissure, and the anterior angle with the serrated margin for articulation with the zygomatic bone.

The **small wings** (alæ parvæ) of the sphenoidal bone are two triangular plates, which project lateralwards from the upper and anterior parts of the body, and end in sharp points (figs. 291, 292). The *cerebral surface* of each is smooth, and supports a small part of the frontal lobe of the brain. The *inferior surface* forms the posterior part of the roof of the orbit, and the upper boundary of the *superior orbital fissure*; it overhangs the anterior part of the middle fossa

* The lesser superficial petrosal nerve sometimes passes through a special canal (*canaliculus innominatus* of Arnold) on the medial side of the foramen spinosum.

of the skull. The superior orbital fissure is triangular in shape, and leads from the cranial cavity into that of the orbit; it is bounded medially by the body of the sphenoidal bone; above, by the small wing; below, by the medial margin of the orbital surface of the great wing; and is completed laterally, between the great and small wings, by the frontal bone. It transmits to the orbital cavity the oculomotor, trochlear, and abducent nerves, the three branches of the ophthalmic division of the trigeminal nerve, and some filaments from the cavernous plexus of the sympathetic; and from the orbital cavity the recurrent meningeal branch of the lacrimal artery, and the ophthalmic veins. The *frontal or anterior border* of the small wing is serrated for articulation with the posterior edge of the orbital plate of the frontal bone. The *posterior border* is smooth and projects into the lateral cerebral fissure; the medial end of this border forms the *anterior clinoid process* which gives attachment to the anterior end of the free border of the tentorium cerebelli. The anterior and middle clinoid processes are sometimes united by a spicule of bone, and when this occurs the end of the groove for the internal carotid artery is converted into a foramen (*caroticoclinoid foramen*). The small wing is connected to the body by two roots, the upper thin and flat, the lower thick and triangular; between these is the *optic foramen*, for the transmission of the optic nerve and ophthalmic artery to the orbital cavity.

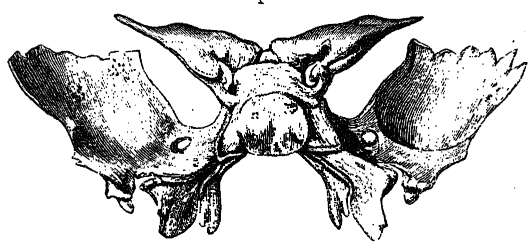
The **pterygoid processes** of the sphenoidal bone (figs. 292, 293), one on either side, descend perpendicularly from the regions where the body and great wings unite. Each process consists of a medial and a lateral lamina, the upper parts of which are fused anteriorly; a shallow groove, the *pterygopalatine sulcus*, descends on the front of the line of fusion, and forms, in the articulated skull, the posterior wall of the pterygopalatine canal. The laminæ are separated below by an angular cleft, the *pterygoid fissure*, the rough margins of which articulate with the pyramidal process of the palatine bone. The two laminæ diverge behind, and between them is the wedge-shaped *pterygoid fossa* which contains the Pterygoideus internus and Tensor veli palatini. Above this fossa is a small, oval, shallow depression, the *scaphoid fossa*, which gives origin to part of the Tensor veli palatini. The anterior surface of the pterygoid process is broad and triangular near its root, where it forms the posterior wall of the pterygopalatine fossa; on it is the anterior orifice of the *pterygoid canal*.

The *lateral lamina* of the pterygoid process is broad, thin, and everted; its *lateral surface* forms part of the medial wall of the infratemporal fossa, and gives origin to the lower head of the Pterygoideus externus; its *medial surface* forms the lateral wall of the pterygoid fossa, and gives origin to the greater part of the Pterygoideus internus. The lower part of its *anterior border* articulates with the palatine bone; its *posterior border* is free.

The *medial lamina* of the pterygoid process is narrower and longer than the lateral; its lower extremity curves lateralwards into a hook-like process, the *pterygoid hamulus*, around which the tendon of the Tensor veli palatini glides. The *lateral surface* of this lamina forms the medial wall of the pterygoid fossa, and the Tensor veli palatini lies against it; the *medial surface* constitutes the lateral boundary of the choana or posterior aperture of the corresponding nasal cavity. Superiorly the medial lamina is prolonged on to the under surface of the body as a thin plate, named the *vaginal process*, which articulates anteriorly with the sphenoidal process of the palatine bone and medially with the ala of the vomer. On the under surface of the vaginal process is a furrow which is converted into a canal by the sphenoidal process of the palatine bone; this canal transmits the pharyngeal branch of the internal maxillary artery and the pharyngeal nerve from the sphenopalatine ganglion. The posterior margin of the medial lamina gives attachment in its entire length to the pharyngobasilar fascia (pharyngeal aponeurosis), and from the lower one-third of this margin the Constrictor pharyngis superior takes origin. At the upper end of this margin is a small pyramidal process named the *pterygoid tubercle*, immediately above which is the posterior opening of the pterygoid canal. Projecting backwards from near the middle of the margin is an angular process, the *processus tubarius*, which supports the pharyngeal end of the auditory tube. The anterior margin of the lamina articulates with the posterior border of the vertical part of the palatine bone.

The **sphenoidal conchæ** (fig. 293) are two thin, curved plates, situated at the anterior and lower parts of the body of the sphenoidal bone; the upper, concave surface of each forms the anterior wall and a part of the floor of the corresponding sphenoidal air-sinus. The sphenoidal conchæ are usually more or less destroyed in the process of disarticulating the skull, but when seen *in situ*, each consists of an anterior, vertical, quadrilateral part and a posterior, horizontal, triangular part. The anterior, vertical portion consists of, (*a*) an upper and lateral, depressed area which completes the posterior ethmoidal air-sinuses and articulates below with the orbital process of the palatine bone; and (*b*) a lower and medial area, smooth and triangular, which forms part of the roof of the nasal cavity, and is perforated near its superior angle by a round opening through which the sphenoidal air-sinus communicates with the spheno-ethmoidal recess of the nasal cavity. The anterior, vertical portions of the two bones meet in the middle line, and are protruded downwards as the sphenoidal crest. The horizontal triangular portion of the concha forms a part of the roof of the nasal cavity, and completes the sphenopalatine foramen; its medial margin articulates with the rostrum of the sphenoidal bone, and with the ala of the vomer; its apex, directed backwards, lies medial to and above the vaginal process of the medial pterygoid lamina, and articulates with the posterior part of the ala of the vomer. A small piece of the sphenoidal concha sometimes appears in the medial wall of the orbit, between the lamina papyracea of the ethmoidal bone in front, the orbital plate of the palatine bone below, and the frontal bone above.

FIG. 294.—The sphenoidal bone at birth. Posterior aspect.



Ossification.—Until the seventh or eighth month of fœtal life the body of the sphenoidal bone consists of two parts—viz. one in front of the tuberculum sellæ, the *presphenoidal part*, with which the small wings are continuous; the other comprising the sella turcica and dorsum sellæ, the *postsphenoidal part*, with which the great wings, and pterygoid processes are associated. A considerable part of the bone is ossified in cartilage. There are six centres for the presphenoidal and eight for the postsphenoidal part.

Presphenoidal part. About the ninth week of fœtal life a centre of ossification appears for each of the small wings, just lateral to the optic foramen; shortly afterwards two centres appear in the presphenoidal part of the body. The sphenoidal conchæ are each developed from a centre which makes its appearance about the fifth month *; at birth they consist of small triangular laminæ; about the third year they become hollowed out and cone-shaped; about the fourth year they fuse with the labyrinths of the ethmoidal bone, and between the ninth and twelfth years with the sphenoidal bone.

Postsphenoidal part.—The first centres of ossification are those for the great wings. One appears below the foramen rotundum in the cartilage which forms the base of each wing about the eighth week. The following portions of the great wing are ossified in membrane, viz.: the parts surrounding the foramen ovale and foramen spinosum, the orbital plate, and the part found in the temporal fossa.† About the fourth month, two centres appear in the postsphenoidal part of the body, one on either side of the sella turcica, and fuse about the middle of fœtal life. Each medial pterygoid lamina (with the exception of its hamulus) is ossified in membrane, and its centre probably appears about the ninth or tenth week; the hamulus is chondrified during the third month, and almost at once begins to ossify.‡ The medial and lateral pterygoid laminæ join about the sixth month. About the fourth month a centre appears for each lingula and speedily joins the rest of the bone.

* According to Cleland, each sphenoidal concha is ossified from four centres.

† E. Fawcett, *Journal of Anatomy and Physiology*, vol. xliv. 1910.

‡ E. Fawcett, *Anatomischer Anzeiger*, March 1905.

The presphenoidal and the postsphenoidal parts of the body fuse about the eighth month of fœtal life, and at birth the bone is in three pieces (fig. 294): a central, consisting of the body and small wings, and two lateral, each comprising a great wing and pterygoid process. In the first year after birth the great wings and body unite, and the small wings extend medialwards above the anterior part of the body, and meet to form an elevated smooth surface, termed the *jugum sphenoidale*. By the twenty-fifth year the sphenoidal and occipital bones are completely fused. In the anterior part of the fossa hypophyseos there are occasionally seen the remains of the *canalis craniopharyngeus*, through which, in early fœtal life, the hypophysial diverticulum of the buccal ectoderm is transmitted (p. 135).

Traces of the sphenoidal air-sinuses are seen as early as the third month of fœtal life, but they do not attain their full size until after puberty.

Certain parts of the sphenoidal bone are connected by ligaments which occasionally ossify. The more important of these ligaments are: the *pterygospinous*, stretching between the spina angularis and the upper part of the lateral pterygoid lamina (see *fascia colli*); the *interclinoid*, joining the anterior to the posterior clinoid process; and the *caroticoclinoid*, connecting the anterior to the middle clinoid process.

Applied Anatomy.—Premature ossification or synostosis of the suture between the pre- and postsphenoidal parts (which normally begins to join at the eighth month) and of the sphenobasilar suture produces a characteristic physiognomy. This is best seen in profile, and consists in an abnormal depression of the bridge of the nose; it is a feature often observed in dwarfs.

Tumours and cysts of the hypophysis are removed by gaining access to the fossa hypophyseos, either from below through the nose and the spenoidal air-sinuses, or from above by raising the brain from the anterior fossa of the cranial cavity.

The Temporal Bones (Ossa Temporalia)

The **temporal bones** are situated at the sides and base of the skull. Each consists of five parts, viz. the *squama*, the *mastoid*, *petrous*, and *tympanic parts*, and the *styloid process*.

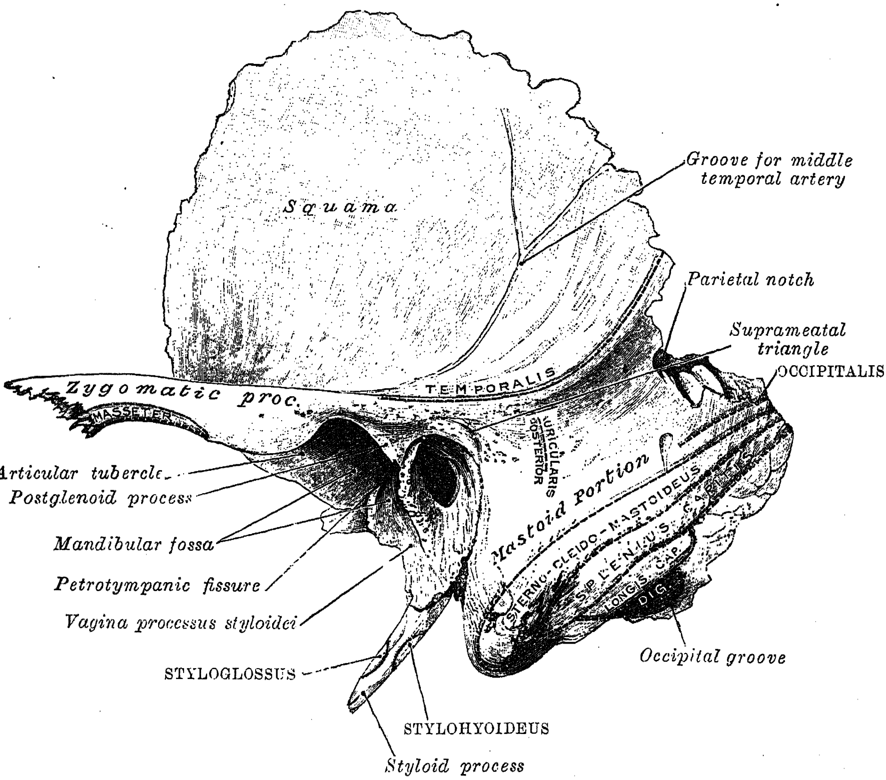
The **squama** of the temporal bone forms the anterior and upper parts of the bone, and is scale-like, thin and translucent. Its *temporal or external surface* (fig. 295) is smooth and slightly convex; it forms part of the temporal fossa and gives origin to the Temporalis muscle; on its hinder part, above the opening of the external acoustic meatus, is a vertical groove for the middle temporal artery. A curved line, the *temporal line* or *supramastoid crest*, courses backwards and upwards, across its posterior part; it serves for the attachment of the temporal fascia, and limits the origin of the Temporalis muscle. The boundary between the squama and the mastoid portion of the bone lies about 1·5 cm. below the temporal line, and is frequently indicated by traces of the original squamosomastoid suture; the external surface of this lower part of the squama is convex, and from its anterior part the Auricularis posterior takes origin. Between the anterior end of the temporal line and the posterosuperior sector of the opening of the external acoustic meatus is an angular depression, the *suprameatal triangle* of Macewen; through this triangle an instrument may be pushed into the tympanic antrum.

Projecting from the lower part of the squama is a long, arched process, the *zygomatic process*. The posterior part of this process is triangular in shape and springs from a broad base; it is directed lateralwards, and its surfaces are superior and inferior. The process is then twisted inwards and runs forwards, and the surfaces of this anterior portion are therefore medial and lateral. The superior surface of the posterior part is concave, and continuous with the temporal surface of the squama; the inferior surface is bounded by two roots, a *posterior* and an *anterior*, which converge as they approach the anterior part of the process. At the meeting point of the two roots is a small tubercle for the attachment of the temporomandibular ligament. The posterior root is prolonged forwards from the surface of the squama immediately above the opening of the external acoustic meatus; its upper border is continuous behind with the temporal line. The anterior root juts almost horizontally from the side of the squama; its inferior surface, convex from before backwards, is smooth for articulation with the articular disc of the

mandibular joint, and the whole root presents the form of a short semi-cylindrical bar, termed the *articular tubercle* (eminentia articularis). The articular tubercle forms the anterior boundary of the mandibular fossa.

The anterior part of the zygomatic process is thin and flat. The superior border, long and thin, gives attachment to the temporal fascia; the inferior, short and arched, gives origin to some fibres of the Masseter. The lateral surface is convex and subcutaneous; the medial is concave, and gives origin to part of the Masseter. The anterior end is deeply serrated and cut obliquely at the expense of the lower border; it articulates with the temporal process of the zygomatic bone. In front of the articular tubercle is a small triangular area which forms a part of the infratemporal fossa, and is separated from the

Fig. 295.—The left temporal bone. External aspect.

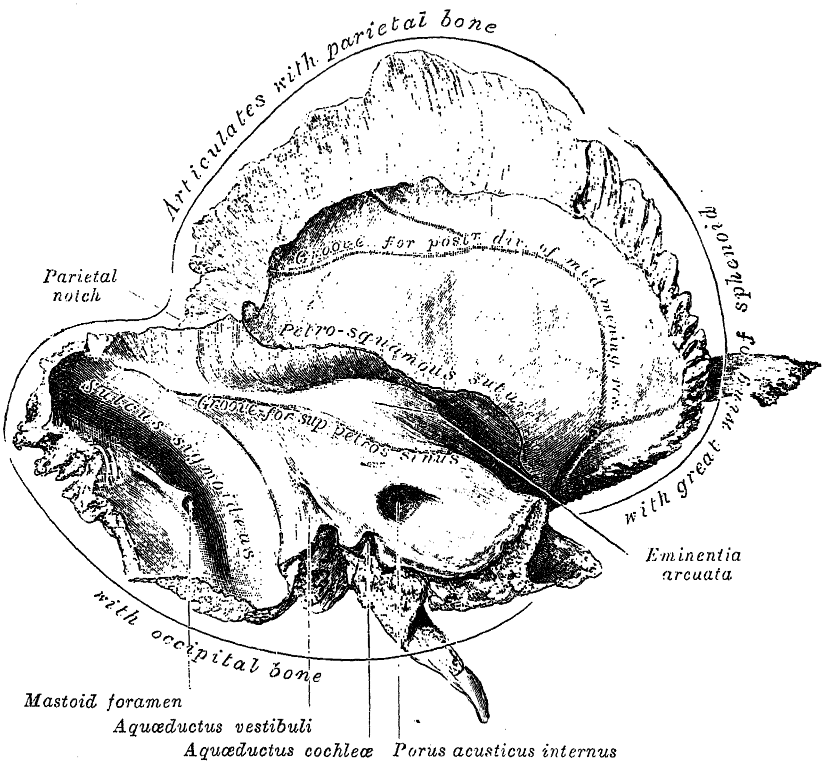


outer surface of the squama by a ridge; this ridge is continuous behind with the anterior root of the zygomatic process, and in front, in the articulated skull, with the infratemporal crest on the great wing of the sphenoidal bone. The *mandibular fossa* (glenoid fossa) is bounded in front by the articular tubercle; it consists of an anterior, articular portion, formed by the squama, and a posterior non-articular portion, formed by the tympanic part of the temporal bone. The articular portion, smooth, oval and deeply concave, articulates with the articular disc of the mandibular joint; the non-articular portion sometimes lodges a small part of the parotid gland. A small, somewhat conical, eminence, the *postglenoid tubercle*, separates the lateral part of the articular portion from the anterior margin of the tympanic part of the bone, and is the representative of a prominent tubercle which, in some mammals, descends behind the condyle of the mandible, and prevents its backward displacement; the postglenoid tubercle is sometimes described as the third root of the zygomatic process. The medial part of the articular portion of the mandibular fossa is separated from the tympanic part of the bone by the lower edge of a plate which projects downwards from the tegmen tympani

of the petrous part of the bone; between this plate and the tympanic part is the *petrotympanic fissure* (Glaserian fissure). This fissure leads into the middle ear or tympanic cavity; it lodges the anterior process of the malleus, and transmits the anterior tympanic branch of the internal maxillary artery. The medial end of the fissure is known as the *canal of Huguier*; it transmits the chorda tympani nerve.

The *cerebral or internal surface* of the squama (fig. 296) is concave; it presents depressions corresponding to the convolutions of the temporal lobe of the brain, and grooves for the branches of the middle meningeal vessels; its lower border is united to the anterior surface of the petrous portion by the *petrosquamosal* suture, traces of which are frequently seen in the adult bone.

FIG. 296.—The left temporal bone. Internal aspect.



The *parietal or superior border* is thin, bevelled at the expense of the internal surface, and overlaps the squamous border of the parietal bone, forming with it the squamosal suture. Posteriorly, the superior border forms an angle, the *parietal notch*, with the mastoid portion of the bone. The *sphenoidal or antero-inferior border*, thin above and thick below, articulates with the great wing of the sphenoidal bone; its upper part is bevelled at the expense of the inner, its lower at the expense of the outer, surface.

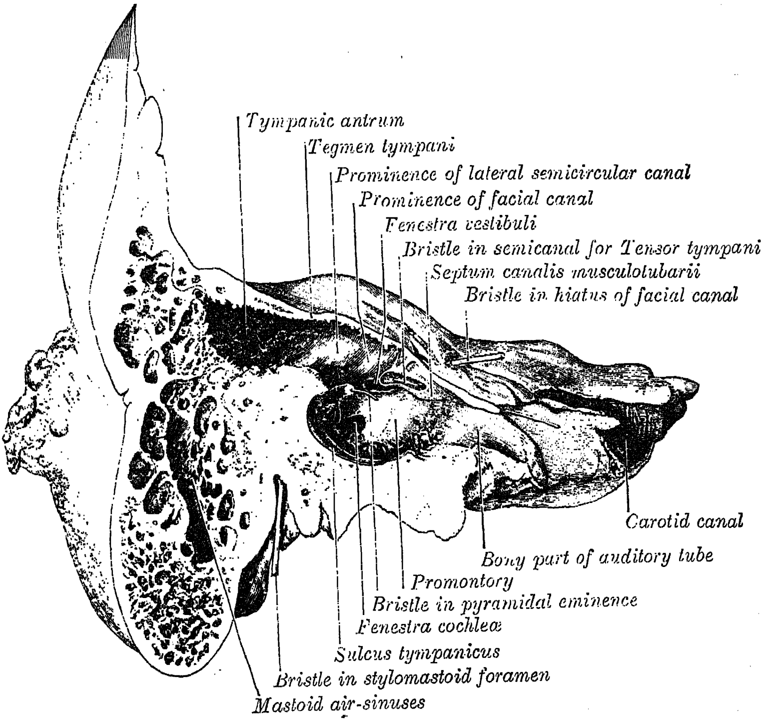
The **mastoid portion** of the temporal bone forms the posterior part of the bone. Its *outer surface* (fig. 295) is rough, and gives attachment to the Occipitalis, and Auricularis posterior. It is frequently perforated near its posterior border by the *mastoid foramen* which transmits a vein from the transverse sinus, and a small branch of the occipital artery to the dura mater; the position and size of this foramen are very variable; it may be situated in the occipital bone, or in the suture between the temporal and the occipital bones. The mastoid portion is continued below into a conical projection, the *mastoid process*, the size and form of which vary somewhat; it is larger in the male than in the female. This process serves for the attachment of the Sternocleido-

mastoideus, Splenius capitis, and Longissimus capitis; on its medial side is a deep groove, the *mastoid notch* (digastric fossa), for the attachment of the posterior belly of the Digastricus; medial to this notch is a shallow furrow, the *occipital groove*, which lodges the occipital artery.

On the *inner surface* of the mastoid portion (fig. 296) there is a deep, curved groove, the *sulcus sigmoideus*, which lodges part of the transverse sinus; in this sulcus is the opening of the mastoid foramen. The sulcus sigmoideus is separated from the innermost of the mastoid air-sinuses by a thin lamina of bone which may be partly deficient.

The *superior border* of the mastoid portion is thick and serrated for articulation with the mastoid angle of the parietal bone. The *posterior border*, also serrated, articulates with the inferior border of the occipital bone between

Fig. 297.—A coronal section through the right temporal bone. Anterior aspect.



the lateral angle and jugular process. Anteriorly the mastoid portion is fused with the descending process of the squama above; below it enters into the formation of the posterior wall of the tympanic cavity.

A section of the mastoid process (fig. 297) exhibits a number of spaces, the *mastoid air-sinuses*, which vary greatly in size and number. At the upper and front part of the process they are large and irregular, but towards the lower part they diminish in size, while those at the apex of the process are frequently quite small; occasionally they are entirely absent, and the mastoid is then solid throughout. In addition to the mastoid air-sinuses a large irregular air-sinus, the *tympanic antrum* (mastoid antrum) is situated in the upper and front part of the process; it is lined with a prolongation of the mucous membrane of the tympanic cavity. It is bounded above by a thin plate of bone, the *tegmen tympani*, which separates it from the middle fossa of the base of the skull; laterally by the part of the squama which lies below the supramastoid crest; on its medial wall is the lateral semicircular canal of the internal ear. Below and behind, the tympanic antrum communicates with the mastoid air-sinuses; in front it opens into that portion of the tympanic cavity which is known as the *attic* or *epitympanic recess*. The tympanic antrum is a cavity of some considerable size at the time of birth;

the mastoid air-sinuses originate as diverticula from the antrum, and begin to appear at or before birth; by the fifth year they are of considerable size, but their development is not completed until puberty.

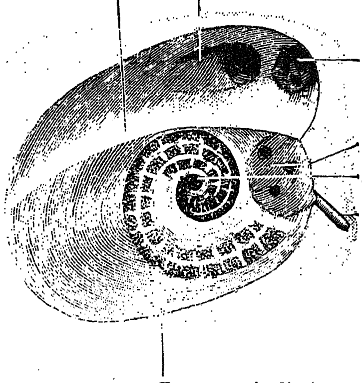
The **petrous portion** or **pyramid** of the temporal bone is wedged between the sphenoidal and occipital bones at the base of the skull (figs. 351, 352). It is directed medialwards, forwards, and a little upwards, and has a base, an apex, three surfaces, and three angles (margins). The essential parts of the organs of hearing and equilibrium are placed within it.

The *base* is fused with the squama and the mastoid portion.

The *apex*, rough and uneven, is received into the angular interval between the posterior border of the great wing of the sphenoidal bone and the basilar part of the occipital bone; it is pierced by the anterior or internal orifice of the carotid canal, and forms the posterolateral boundary of the foramen lacerum.

The *anterior surface* forms the posterior part of the middle fossa of the skull, and is continuous with the inner surface of the squama, to which it is united by the *petrosquamosal suture*, remains of which are distinct even at a late period of life. It is marked by depressions for the convolutions of the

FIG. 298.—A diagrammatic view of the lateral end of the right internal acoustic meatus. (Testut.)

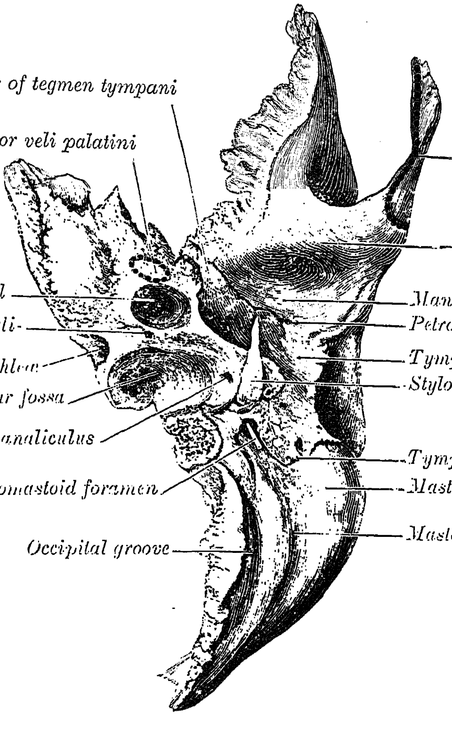


brain, and presents six points for examination: (1) near the centre is the *eminentia arcuata*, which indicates the situation of the superior semicircular canal; (2) in front of and lateral to this eminence is a depressed area which forms the roof of the tympanic cavity and consists of a thin plate of bone known as the *tegmen tympani*; a thin scale of this descends between the squama and the tympanic plate, and forms the anterior boundary of the petrotympanic fissure, and the greater part of the lateral wall of the semicanal for the Tensor tympani muscle; (3) a shallow groove, sometimes double, leads backwards and lateralwards to an oblique opening, the *hiatus of the facial canal*, for the passage of the greater superficial petrosal nerve and the petrosal branch of the middle meningeal artery; (4) lateral to the hiatus there is occasionally a smaller opening for the passage of the lesser superficial petrosal nerve; (5) near the apex of the bone is the end of the carotid canal, the anterior wall of which is deficient; (6) above this canal is the shallow *trigeminal impression* for the reception of the semilunar ganglion of the trigeminal nerve.

The *posterior surface* (fig. 296) forms the anterior part of the posterior fossa of the skull, and is continuous with the inner surface of the mastoid portion. Near the centre of this surface is an orifice of varying size, the *porus acusticus internus* leading into the *internal acoustic meatus*, a canal, about 1 cm. in length, which runs lateralwards. It transmits the facial and acoustic nerves and the internal auditory branch of the basilar artery. The lateral end of the internal acoustic meatus is separated from the internal ear by a vertical plate, which is divided by a horizontal crest, the *crista transversa*, into two unequal portions

(fig. 298). Below the posterior part of the crista transversa, and situated in the *area vestibularis inferior* are several small openings for the transmission of the nerves to the saccule ; below and behind this area is the *foramen singulare*, which gives passage to the nerve to the posterior semicircular duct. Below the anterior part of the crista transversa is the *tractus spiralis foraminosus*, consisting of a number of small spirally arranged openings, which encircle the *canalis centralis cochleæ* ; these openings together with the canalis centralis cochleæ transmit the nerves to the cochlea. The portion above the crista transversa displays behind, the *area vestibularis superior*, pierced by a series of small openings for the passage of the nerves to the utricle and the superior and lateral semicircular ducts, and, in front, the *area facialis*, with one large opening which is the commencement of the *canalis facialis* (aquæductus Fallopii)

FIG. 299.—The left temporal bone. Inferior aspect.



and transmits the facial nerve. Behind the porus acusticus internus is a small slit almost hidden by a thin plate of bone, leading to a canal, the *aquæductus vestibuli*, which contains the ductus endolymphaticus together with a small artery and vein. Above and between these two openings is an irregular depression which lodges a process of the dura mater and transmits a small vein ; in the infant this depression is represented by a large fossa, the *fossa subarcuata*, which extends backwards as a short, blind tunnel under the superior semicircular canal.

The *inferior surface* (fig. 299), rough and irregular, forms part of the external surface of the base of the skull. It presents the following parts for examination : (1) near the apex is a quadrilateral rough surface, which serves partly for the attachment of the Levator veli palatini and the cartilaginous portion of the auditory tube, and partly for connexion with the basilar part of the occipital bone through the intervention of some dense fibrous tissue ; (2) behind this is a large, nearly circular aperture, the inferior opening of the *carotid canal* ; this canal runs at first vertically, and then, making a bend, is directed horizontally forwards and medialwards ; it transmits into the cranium the internal carotid artery, and the carotid plexus of nerves ; (3) behind this opening is a

deep depression, the *jugular fossa*, of variable depth and size in different skulls; it lodges the bulb of the internal jugular vein; (4) in front of the medial part of the jugular fossa and directly below the porus acusticus internus is a triangular depression; at the apex of this depression is a small opening, the *aquæductus cochleæ*, which lodges a tubular prolongation of the dura mater, and transmits a vein from the cochlea to join the internal jugular vein; (5) in the bony ridge dividing the carotid canal from the jugular fossa is the small *inferior tympanic canaliculus* for the passage of the tympanic branch of the glossopharyngeal nerve (nerve of Jacobson); (6) in the lateral part of the jugular fossa is the *mastoid canaliculus* for the entrance of the auricular branch of the vagus nerve (nerve of Arnold); (7) behind the jugular fossa is the *jugular surface*, a rough quadrilateral area covered with cartilage in the recent state, and articulating with the jugular process of the occipital bone; (8) extending lateralwards from the carotid canal is the sharp lower border of the tympanic part of the bone; the lateral part of this border splits to ensheath the root of the styloid process and is therefore named the *vagina processus styloidei* (vaginal process); (9) emerging from its sheath is the *styloid process*, which is about 2·5 cm. in length, and is directed downwards and forwards; (10) between the styloid and mastoid processes is the *stylomastoid foramen*; this foramen is the end of the facial canal, and transmits the facial nerve and stylomastoid artery.

The *superior angle* (superior margin), the longest, is grooved for the superior petrosal sinus, and gives attachment to the tentorium cerebelli; at its medial extremity is a shallow notch, in which the trigeminal nerve lies. The *posterior angle* (posterior margin) is intermediate in length between the superior and the anterior. Its medial part is marked by a sulcus, which forms, with a corresponding sulcus on the occipital bone, the channel for the inferior petrosal sinus. Behind this is the *jugular fossa* which, with the jugular notch on the occipital bone, forms the jugular foramen; an eminence occasionally projects from the centre of the fossa, and divides the foramen into two. The *anterior angle* (anterior margin) is divided into two parts—a lateral, joined to the squama at the *petrosquamosal* suture; a medial, free, for articulation with the great wing of the sphenoidal bone.

At the angle of junction of the petrous part and the squama are two canals placed one above the other, and separated by a thin plate of bone, the *septum canalis musculotubarii* (processus cochleariformis). Both canals lead into the tympanic cavity; the upper (semicanalis m. tensoris tympani) transmits the Tensor tympani, the lower (semicanalis tubæ auditivæ) forms the bony part of the auditory tube.

The **tympanic part** of the temporal bone (fig. 299) is a curved plate lying below the squama and in front of the mastoid process. Internally, it is fused with the petrous portion, and appears in the angle between it and the squama, where it lies below and lateral to the orifice of the auditory tube. Behind, it fuses with the squama and the mastoid process, and forms the anterior boundary of the tympanomastoid fissure. Its *posterior surface* is concave, and forms the anterior wall, the floor, and a part of the posterior wall of the bony external acoustic meatus; at the medial end of this surface is a narrow furrow, the *tympanic sulcus*, for the attachment of the circumference of the tympanic membrane. Its *anterior surface*, quadrilateral and slightly concave, constitutes the posterior wall of the mandibular fossa, and is sometimes in contact with a part of the parotid gland. Its *lateral border*, free and rough, forms a large part of the margin of the *porus acusticus externus*, and gives attachment to the cartilaginous part of the external acoustic meatus. The lateral part of the *upper border* is fused with the back of the postglenoid process; its medial part forms the posterior boundary of the petrotympanic fissure. The *lower border* is sharp; its lateral part splits to enclose the root of the styloid process, and is therefore named the vagina processus styloidei (vaginal process). The central portion of the tympanic part of the temporal bone is thin, and in a considerable percentage of skulls is perforated by the *foramen of Huschke*.

The *external accustic meatus*, about 16 mm. long, is directed inwards and slightly forwards and downwards, and the floor of the meatus is convex upwards. In sagittal section the meatus is oval or elliptical in shape with the long axis directed downwards and slightly backwards. Its anterior wall and floor and the lower part of its posterior wall are formed by the tympanic part of the

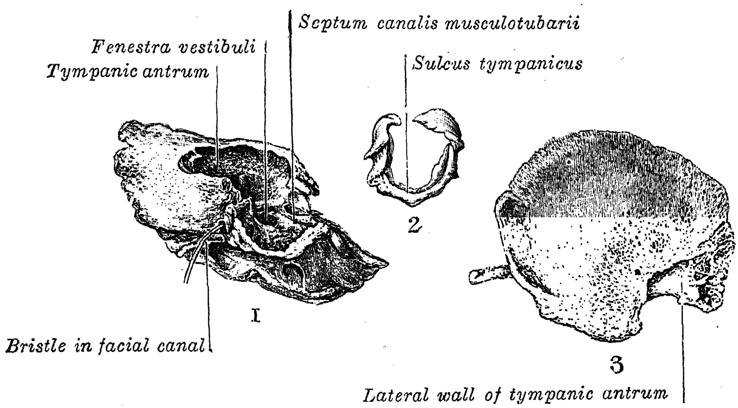
bone ; the roof and the upper part of the posterior wall by the squama. Its inner end is closed, in the recent state, by the tympanic membrane ; its outer end (*porus acusticus externus*) is bounded above by the posterior root of the zygomatic process, below which a small spine, the *suprameatal spine,* is sometimes seen at the upper and posterior part of the orifice.

The **styloid process** of the temporal bone, slender, pointed, and averaging about 2·5 cm. in length, projects downwards and forwards, from the under surface of the temporal bone. Its proximal part (tympanohyal) is surrounded by its sheath (vagina processus styloidei), while its distal part (stylohyal) gives attachment to the stylohyoid and stylomandibular ligaments, and to the Styloglossus, Stylohyoideus and Stylopharyngeus muscles.

Structure.—The structure of the squama is like that of the other cranial bones : the mastoid portion is spongy, and the petrous portion dense and hard.

Ossification.—The temporal bone is ossified from eight centres (exclusive of those for the internal ear and the tympanic ossicles)—viz. one each for the squama and the tympanic part, four for the petrous and mastoid parts, and two for the

FIG. 300.—The three principal parts of the right temporal bone at birth.



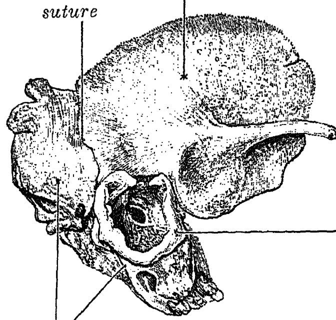
1. External aspect of petromastoid part. 2. Internal aspect of tympanic ring. 3. Internal aspect of squama.

styloid process. Just before the close of fœtal life the bone consists of three principal parts, viz. : the squama, the petromastoid part, and the tympanic ring (fig. 300). The *squama* is ossified in membrane from a single centre which appears near the root of the zygomatic process about the seventh or eighth week of fœtal life. The *petromastoid* part is developed from four centres, which make their appearance in the cartilaginous ear-capsule (p. 107) about the fifth or sixth month of fœtal life. One (pro-otic) appears in the neighbourhood of the eminentia arcuata, spreads in front of and above the internal acoustic meatus and extends to the apex of the bone ; it covers part of the cochlea, vestibule, superior semicircular canal, and medial wall of the tympanic cavity. A second (opisthotic) appears at the promontory on the medial wall of the tympanic cavity and surrounds the fenestra cochleæ ; it forms the floor of the tympanic cavity and vestibule, surrounds the carotid canal, invests the lateral and lower parts of the cochlea, and spreads medially below the internal acoustic meatus. A third (pterotic) roofs in the tympanic cavity and antrum ; while the fourth (epiotic) appears near the posterior semicircular canal and extends to form the mastoid process (Vrolik). The *tympanic ring* is an incomplete circle the concavity of which is grooved by the tympanic sulcus, for the attachment of the circumference of the tympanic membrane.* The tympanic ring expands to form the tympanic part of the bone, and is ossified in membrane from a single centre which appears about the third month. The *styloid process* is developed from the cranial end of the cartilage of the second branchial or hyoid arch (p. 77)

* Two crests, the *superior and inferior tympanic crests,* run obliquely downwards and forwards across the anterior part of the inner surface of the tympanic ring. Between them is an obliquely directed furrow, the *sulcus malleolaris,* which lodges the anterior process of the malleus, the anterior tympanic artery and the chorda tympani nerve.

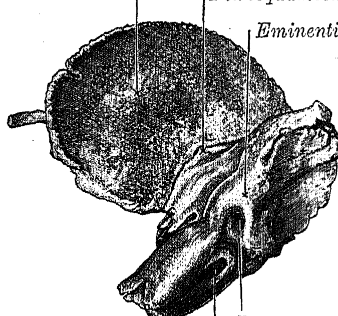
by two centres: one for the proximal part of the process, the tympanohyal, appears before birth; the other, for the distal part of the process, the stylohyal, does not appear until after birth. The tympanic ring unites with the squama shortly before birth; the petromastoid part and the squama join during the first year, and the tympanohyal portion of the styloid process about the same time (figs. 301, 302). The stylohyal does not unite with the rest of the bone until after puberty, and in some skulls never at all.

FIG. 301.—The temporal bone at birth. External aspect.



The chief subsequent changes in the temporal bone apart from increase in size are: (1) The tympanic ring grows lateralwards and backwards to form the tympanic part of the bone. This extension does not, however, take place at an equal rate all round the circumference of the ring, but occurs most rapidly on its anterior and posterior portions, and these outgrowths meet and blend, and thus, for a time, there exists in the floor of the meatus a foramen, the *foramen of Huschke*; this foramen is usually closed about the fifth year, but may persist throughout life. (2) The mandibular fossa is at first extremely shallow, and looks more lateralwards than downwards; it becomes deeper and is ultimately directed downwards. Its change in direction is accounted for as follows. The part of the squama which forms the fossa lies at first below the level of the zygomatic process and is nearly vertical, but in consequence of the subsequent increase in the width of the base of the skull this part of the squama comes to be directed horizontally inwards, and its surfaces therefore upwards and downwards; the attached portion of the zygomatic process also becomes everted and projects like a shelf at right angles to the squama. (3) The mastoid portion is at first flat, and the stylomastoid foramen and rudimentary styloid process lie immediately behind the tympanic ring. With the development of the mastoid air-sinuses the lateral part of the mastoid portion grows downwards and forwards to form the mastoid process, and the styloid process and stylomastoid foramen come to lie on the under surface of the bone. The descent of the stylomastoid foramen is necessarily accompanied by a corresponding increase in the length of the canal for the facial nerve. (4) The downward and forward growth of the mastoid process also pushes forward the tympanic part of the bone, so that the portion of the latter which formed the original floor of the external acoustic meatus and contained the foramen of Huschke ultimately constitutes the anterior wall of the meatus. (5) The fossa subarcuata on the posterior surface of the petrous portion is gradually filled and almost obliterated.

FIG. 302.—The temporal bone at birth. Internal aspect.



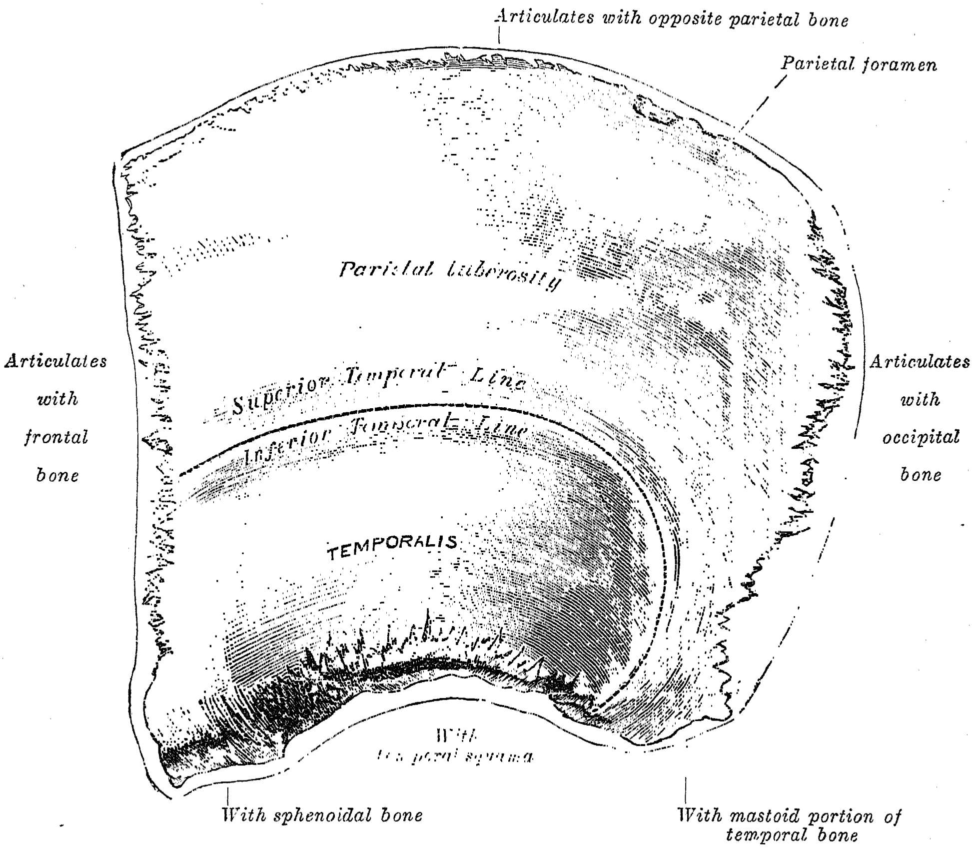
Applied Anatomy.—The external acoustic meatus is relatively as long in the child as in the adult, but in the child the canal is cartilaginous, whereas in the adult the inner

two-thirds of it are osseous. When it is necessary to open the tympanum for suppuration, it is approached through the tympanic antrum. In the child only a thin scale of bone requires to be removed from the suprameatal triangle to open into the tympanic antrum.

The Parietal Bones (Ossa Parietalia)

The **parietal bones** form, by their union, the sides and the roof of the cranium. Each bone is irregularly quadrilateral in shape, and has two surfaces, four borders, and four angles.

Fig. 303.—The left parietal bone. External aspect.



The *parietal* or *external surface* (fig. 303) is convex, smooth, and marked near the centre by an eminence, the *parietal tuberosity or eminence.* Crossing the middle of the bone in an arched direction are two curved lines, the *superior and inferior temporal lines*; the former gives attachment to the temporal fascia, and the latter indicates the upper limit of the origin of the Temporalis. The part of the bone above these lines is covered, in the recent condition, with the galea aponeurotica; that below the lines forms a part of the temporal fossa. At the posterior part and close to the upper or sagittal border is the *parietal foramen,* which transmits a vein from the superior sagittal sinus, and sometimes a small branch of the occipital artery; the foramen is not constantly present, and its size varies considerably.

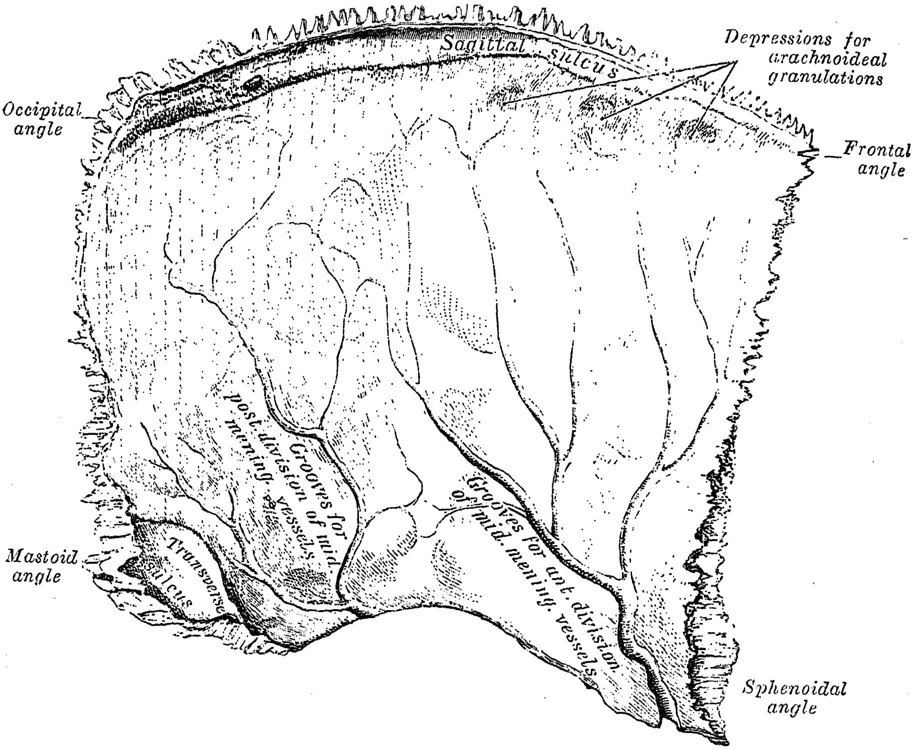
The *cerebral or internal surface* (fig. 304) is concave; it presents depressions corresponding to the cerebral convolutions, and numerous furrows for the ramifications of the middle meningeal vessels *; these furrows run upwards

* Consult articles by F. Wood Jones, *Journal of Anatomy and Physiology*, vol. xlvi., and B. Coen, *Journal of Anatomy and Physiology*, vol. xlviii.

and backwards from the sphenoidal angle, and from the central and posterior part of the squamous border. Along the upper or sagittal border is a shallow groove, which, with that on the opposite parietal bone, forms the *sagittal sulcus*, for the superior sagittal sinus; to the edges of this sulcus the falx cerebri is attached. Near the sulcus are several depressions, best marked in the skulls of old persons, for the arachnoideal granulations (glandulæ Pacchionii).

The *sagittal border*, the longest and thickest, is dentated; it articulates with the corresponding border of the opposite parietal bone, to form the sagittal suture. The *squamous border* is divided into three parts: of these, the anterior, short, thin and pointed, is bevelled at the expense of the external surface, and

Fig. 304.—The left parietal bone. Internal aspect.



overlapped by the tip of the great wing of the sphenoidal bone; the middle portion is arched, bevelled at the expense of the external surface, and overlapped by the squama of the temporal bone; the posterior part, short, thick and serrated, articulates with the mastoid portion of the temporal bone. The *frontal border* is deeply serrated, and bevelled at the expense of the external surface above and of the internal below; it articulates with the frontal bone, forming one-half of the coronal suture. The *occipital border*, deeply dentated, articulates with the occipital bone, forming one-half of the lambdoid suture.

The *frontal angle* is almost a right angle, and corresponds with the *bregma* or point of meeting of the sagittal and coronal sutures. The *sphenoidal angle*, thin and acute, is received into the interval between the frontal bone and the great wing of the sphenoidal bone. Its internal surface is marked by a deep groove, sometimes a canal, for the anterior divisions of the middle meningeal vessels. In some skulls the frontal bone articulates with the squama of the temporal bone, and the parietal bone then fails to reach the great wing of the sphenoidal bone. The *occipital angle* is rounded and corresponds with the *lambda* or point of meeting of the sagittal and lambdoid sutures. The *mastoid angle* is blunt, and articulates with the occipital bone and with the mastoid portion of the temporal bone, the meeting point of the three bones being named

the *asterion*. On the internal surface of this angle is a broad, shallow groove which lodges a small part of the transverse sinus.

At birth there are unossified or membranous intervals in the skull at the angles of the parietal bones; they are named fonticuli (fontanelles) and are described on pp. 267, 268.

Ossification.—The parietal bone is ossified in membrane from two centres, which appear one above the other at the parietal tuberosity about the seventh week of fœtal life. These centres unite early, and ossification gradually extends in a radial manner towards the margins of the bone; the angles are consequently the parts last formed, and it is here that the fonticuli are found. At birth the temporal lines are situated low down; they only reach their permanent position after the eruption of the molar teeth. Occasionally the parietal bone is divided into two parts, upper and lower, by an anteroposterior suture.

The Frontal Bone (Os Frontale)

The **frontal bone** resembles a cockle-shell in form, and consists of two portions—a vertical part, the *squama*, corresponding with the region of the forehead; and a horizontal or *orbital part*, which enters into the formation of the roofs of the orbital and nasal cavities.

The **squama** of the frontal bone has two surfaces, an external and an internal.

The *external surface* of the squama (fig. 305) is convex and divided into a large frontal and two small temporal surfaces by lines which arch backwards across the lateral parts of the bone.

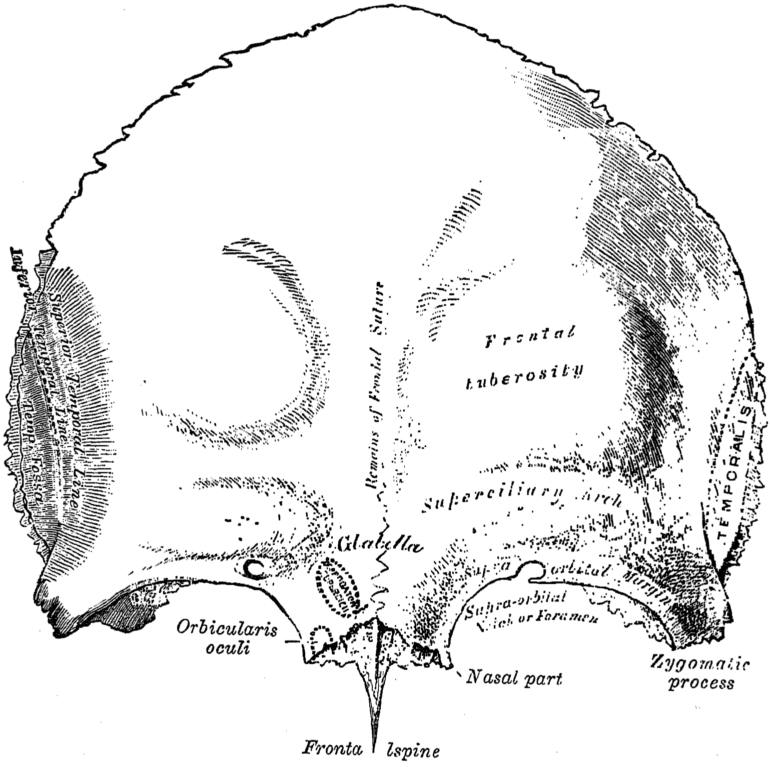
The *frontal surface* usually exhibits, in the lower part of the middle line, the remains of the *frontal or metopic suture*; in infancy this suture divides the bone into two, a condition which persists in about 9 per cent. of skulls. On either side of the middle line, about 3 cm. above the supra-orbital margin, is a rounded elevation, the *frontal tuberosity or eminence*. These tuberosities vary in size in different individuals, are occasionally unsymmetrical, and are especially prominent in young skulls. Below the frontal tuberosities, and separated from them by a shallow groove, are two curved elevations, the *superciliary arches*, the medial parts of which are prominent, and joined to one another by a smooth elevation named the *glabella*. These arches are larger in the male than in the female, and their degree of prominence depends to some extent on the size of the frontal air-sinuses; prominent superciliary arches are, however, occasionally associated with small air-sinuses. Beneath the superciliary arches are the curved *supra-orbital margins*, which form the upper boundaries of the bases of the orbits, and separate the squama from the orbital portion of the bone. The lateral two-thirds of each supra-orbital margin is sharp; the medial one-third is rounded. At the junction of these two parts is the *supra-orbital notch or foramen* which transmits the supra-orbital vessels and nerve. Medial to this notch, and present in about 50 per cent. of skulls, is the small *frontal notch or foramen*. The supra-orbital margin ends laterally in the *zygomatic process*, which is strong and prominent, and articulates with the zygomatic bone. Curving upwards and backwards from this process is a line which soon divides into the *superior and inferior temporal lines*.

The portion of the squama which projects downwards between the supra-orbital margins is named the *nasal part*. It presents an uneven interval, the *nasal notch*, which articulates on either side of the middle line with the nasal bone, and lateral to this with the frontal process of the maxilla and with the lacrimal bone. From the centre of the notch the *nasal process* projects downwards and forwards beneath the nasal bones and frontal processes of the maxillæ, and supports the bridge of the nose. The nasal process ends below in a sharp *frontal spine*, and on either side of this is a small grooved surface which forms a part of the roof of the corresponding nasal cavity. The frontal spine forms a part of the septum of the nose; in front it articulates with the crest of the nasal bones, behind with the lamina perpendicularis of the ethmoidal bone (fig. 322).

The *temporal surface*, below and behind the temporal lines, forms the anterior part of the temporal fossa, and gives origin to a part of the Temporalis muscle.

The *cerebral or internal surface* (fig. 306) of the squama is concave. In the upper part of the middle line is a vertical groove, the *sagittal sulcus*, the edges of which unite below to form the *frontal crest*; the sulcus lodges the anterior part of the superior sagittal sinus, while to its margins and to the frontal crest the anterior part of the falx cerebri is attached. The crest ends below in a small notch which is converted into the *foramen cæcum* by articulation with the ethmoidal bone. The foramen cæcum varies in size in different skulls, and is often pervious; when this is so, it transmits a vein from the nose to the superior sagittal sinus. On either side of the middle line are depressions for the

FIG. 305.—The frontal bone. External aspect.



convolutions of the brain, and minute furrows for the anterior branches of the middle meningeal vessels. Several small, irregular fossæ may be seen on either side of the sagittal sulcus, for the reception of arachnoideal granulations.

The *border of the squama* is thick, strongly serrated, bevelled at the expense of the cerebral surface above, where it rests upon the parietal bones, and at the expense of the temporal surface on either side, where it receives the lateral pressure of the parietal bones; it is continued below into a triangular, rough surface, for articulation with the great wing of the sphenoidal bone.

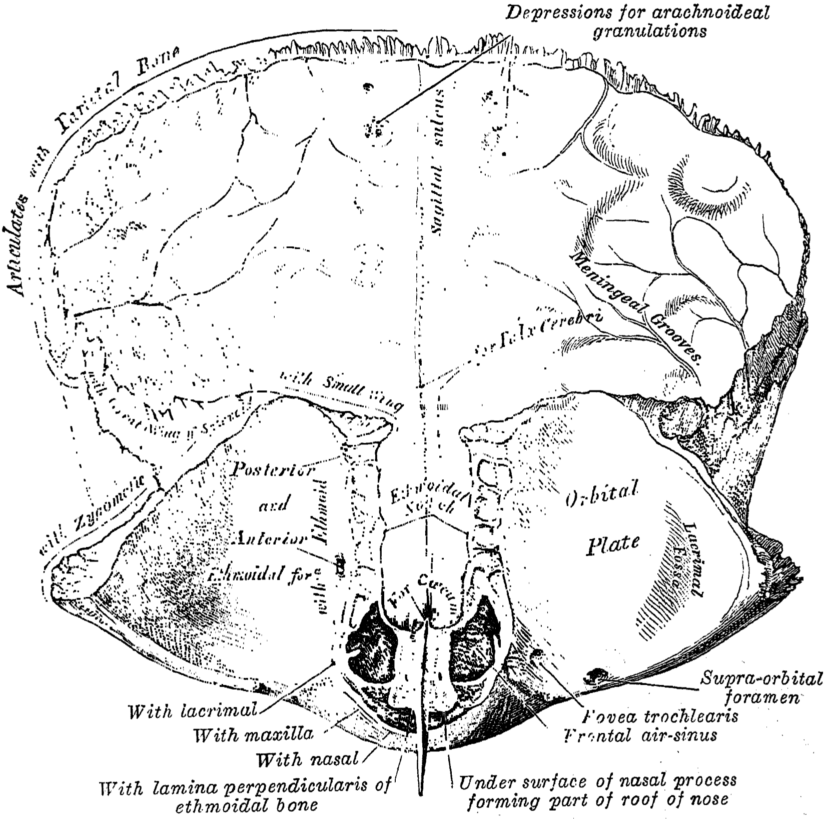
The **orbital part** of the frontal bone consists of two thin triangular *orbital plates*, which form the vaults of the orbits, and are separated from one another by a wide gap, the *ethmoidal notch*.

The *orbital surface* (fig. 306) of each orbital plate is smooth and concave, and presents, laterally, under cover of the zygomatic process, a shallow depression, the *lacrimal fossa*, for the lacrimal gland; below and behind the medial end of the supra-orbital margin, about midway between the supra-orbital **notch** and the frontolacrimal suture, is a small depression or spine, the *fovea vel spina trochlearis*, for the attachment of the fibrocartilaginous pulley of the Obliquus oculi superior. The *cerebral surface* is convex, and marked by depressions

corresponding to the convolutions on the inferior surface of the frontal lobe of the brain, and by faint grooves for the meningeal branches of the ethmoidal vessels.

The *ethmoidal notch* (incisura ethmoidalis) (fig. 306) separates the two orbital plates; it is quadrilateral, and filled, in the articulated skull, by the lamina cribrosa of the ethmoidal bone. On the margins of the notch are portions of several air-sinuses which complete the ethmoidal air-sinuses when the ethmoidal bone is in position. Two transverse grooves cross each margin of the notch; they are converted into the *anterior and posterior ethmoidal canals* by

FIG. 306.—The frontal bone. Internal and inferior aspects.



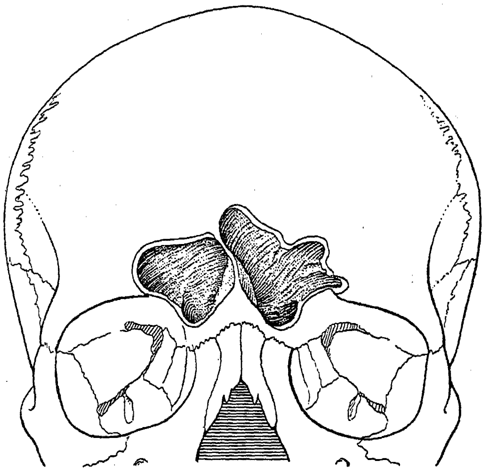
the ethmoidal bone, and open on the medial wall of the orbit; they transmit the anterior and posterior ethmoidal nerves and vessels.

In front of the ethmoidal notch, and lateral to the frontal spine, are the openings of the *frontal air-sinuses* (fig. 307). These air-sinuses are two irregular cavities, which extend backwards, upwards, and lateralwards for a variable distance between the tables of the frontal bone; they are separated from one another by a thin bony septum, which is often deflected to one or other side of the median plane, with the result that the sinuses are seldom symmetrical. Rudimentary at birth, the frontal air-sinuses are usually fairly well-developed between the seventh and eighth years, but only reach their full size after puberty. They vary in size in different persons, and are larger in men than in women.* Occasionally they extend backwards in the roofs of the orbit

* Logan Turner (*op. cit.*) gives the following measurements for an adult sinus of average size: height, 3·16 cm.; breadth, 2·58 cm.; depth from before backwards, 1·8 cm. Onodi (*op. cit.*) states that in infants of from one to twelve months the height of the frontal sinus varies from 3·5 mm. to 8 mm., and its width from 2 mm. to 6 mm., and that in the eighth year of life the height is from 14 mm. to 17 mm., and the width from 7 mm. to 9 mm.

cavities as far as the optic foramina. Each communicates with the middle meatus of the corresponding nasal cavity by means of a passage called the *frontonasal duct.*

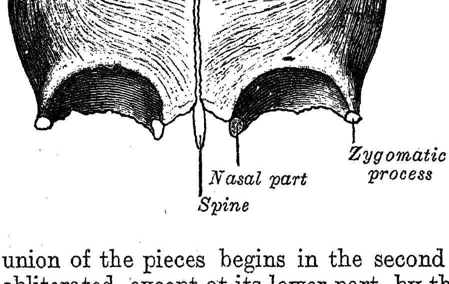
FIG. 307.—Frontal air-sinuses. Anterior aspect. The left sinus is larger than the right and the septum between them is obliquely placed.



The *posterior borders of the orbital plates* are thin and serrated, and articulate with the small wings of the sphenoidal bone; the lateral part of each usually appears in the middle fossa of the skull between the great and small wings of the sphenoidal bone.

Structure.—The squama and the zygomatic process of the frontal bone are thick and consist of spongy substance contained between two compact laminæ; the spongy substance is absent in the regions occupied by the frontal air-sinuses. The orbital part, composed entirely of compact bone, is thin and translucent in its posterior two-thirds.

FIG. 308.—The frontal bone at birth. External aspect.



Ossification.—(fig. 308) The frontal bone is ossified in membrane from two primary centres which appear in the seventh or eighth week of fœtal life, one above each supra-orbital margin. From each of these centres ossification extends upwards to form the corresponding half of the squama, and backwards to form the orbital plate. The frontal spine is ossified from two secondary centres, one on either side of the middle line; secondary centres also appear in the nasal parts and zygomatic processes. At birth the bone consists of two pieces separated by the frontal suture, but union of the pieces begins in the second year, and the frontal suture is usually obliterated, except at its lower part, by the eighth year.

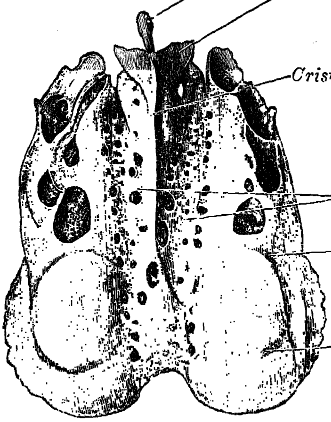
THE ETHMOIDAL BONE (OS ETHMOIDALE)

The **ethmoidal bone** is cubical in shape, and exceedingly light; it is situated at the anterior part of the base of the cranium, and assists in forming the medial walls of the orbital cavities and the roofs and lateral walls of the

nasal cavities. It consists of four parts : a horizontal, perforated plate named the lamina cribrosa, a lamina perpendicularis, and two labyrinths or lateral masses.

The **lamina cribrosa** of the ethmoidal bone (fig. 309) occupies the ethmoidal notch of the frontal bone and forms a part of the roofs of the nasal cavities. Projecting upwards from the median line of this lamina is a thick, smooth, triangular process, the *crista galli*, so called from its resemblance to a cock's comb. Its posterior border, long, thin, and curved, gives attachment to the falx cerebri. Its anterior border, short and thick, articulates with the frontal bone by two small projecting *alar processes* which complete the foramen cæcum. Its sides are smooth, and sometimes bulging owing to the presence of a small air-sinus in the interior. On either side of the crista galli, the lamina cribrosa is narrow and depressed ; it supports the olfactory bulb and is perforated by foramina for the passage of the olfactory nerves. The foramina in its middle part are small and transmit the nerves to the mucous membrane of the roof of the nasal cavity ; those in the medial and lateral parts are larger —the former transmit the nerves to the mucous membrane on the upper part of the nasal septum, the latter the nerves to the mucous membrane on the superior nasal concha. At the front part of the lamina cribrosa, on either side of the crista galli, is a small fissure which is occupied by a process of dura mater. Lateral to this fissure is a foramen which transmits the anterior ethmoidal nerve to the nasal cavity ; from this foramen a groove runs backwards to the anterior ethmoidal foramen.

Fig. 309.—The ethmoidal bone. Superior aspect.



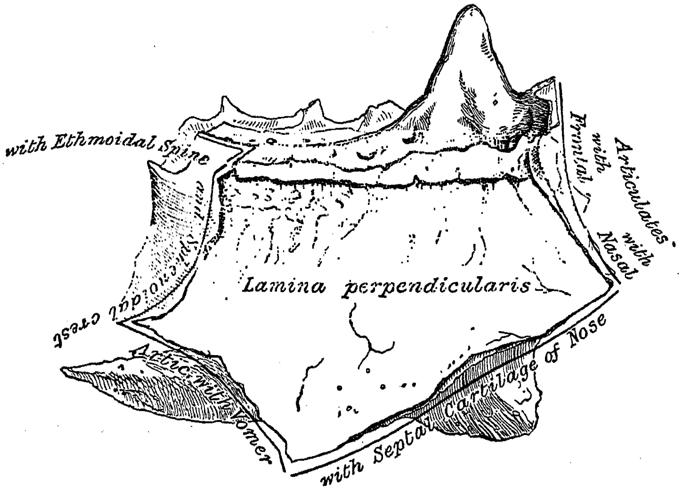
The **lamina perpendicularis** of the ethmoidal bone (figs. 310, 311), thin, flat, and somewhat quadrilateral in form, descends from the under surface of the lamina cribrosa, and forms the upper part of the nasal septum ; it is generally deflected a little to one or other side. The *anterior border* articulates with the spine of the frontal bone and the crest of the nasal bones. The *posterior border* articulates with the sphenoidal crest above and with the vomer below. The *superior border* is attached to the lamina cribrosa. The *inferior border* is thick, and serves for the attachment of the cartilage of the septum of the nose. The surfaces of the lamina are smooth, except above, where numerous grooves and canals are seen ; these lead from the medial foramina in the lamina cribrosa and lodge filaments of the olfactory nerves.

Each **labyrinth** or **lateral mass** of the ethmoidal bone consists of a number of thin-walled *ethmoidal air-sinuses*, arranged in three groups, *anterior*, *middle*, and *posterior*, and interposed between two vertical plates of bone ; the lateral plate forms part of the medial wall of the orbit, the medial plate, part of the lateral wall of the nasal cavity.* In the disarticulated bone many of these ethmoidal air-sinuses are opened into, but in the articulated skull they are everywhere closed, except at their apertures of communication with the nasal cavity. The *upper surface* of the labyrinth (fig. 309) presents a number of air-sinuses, the walls of which are completed, in the articulated skull, by the edges of the ethmoidal notch of the frontal bone. Crossing this surface are two grooves which are converted into the *anterior and posterior ethmoidal canals*

* Some anatomists divide the ethmoidal air-sinuses into two groups, an *anterior*, comprising those which open into the middle meatus, and a *posterior*, those which open into the superior meatus of the nose.

by articulation with the frontal bone. On the *posterior surface* of each labyrinth (fig. 311) are large air-sinuses the walls of which are completed by the sphenoidal concha and the orbital process of the palatine bone. The *lateral surface* (fig. 312) consists of a thin, smooth, oblong plate, the *lamina papyracea*

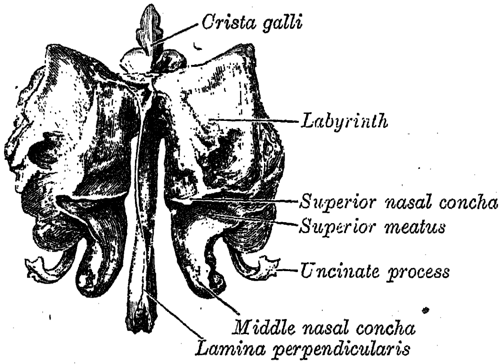
FIG. 310.—The lamina perpendicularis of the ethmoidal bone. Right lateral aspect. Shown by removing the right labyrinth.



(os planum), which covers the middle and posterior ethmoidal air-sinuses and forms a large part of the medial wall of the orbit; it articulates above with the orbital plate of the frontal bone, below with the maxilla and the orbital process of the palatine bone, in front with the lacrimal bone, and behind with the sphenoidal bone (fig. 328).

In front of the lamina papyracea are some air-sinuses, the walls of which are completed by the lacrimal bone and the frontal process of the maxilla. A curved lamina, the *uncinate process*, projects downwards and backwards from this part of the labyrinth; it forms a small part of the medial wall of the maxillary air-sinus (fig. 328), and articulates with the ethmoidal process of the inferior nasal concha.

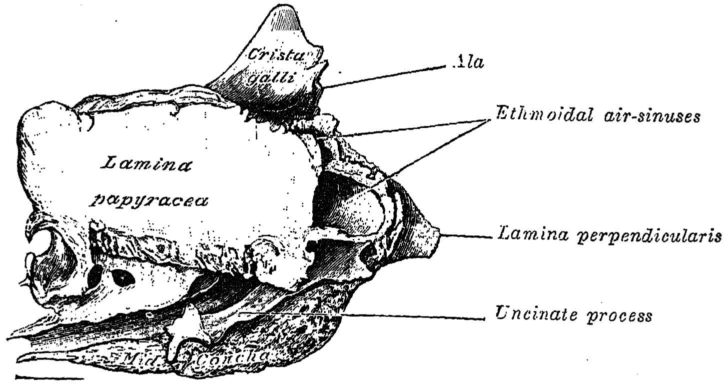
FIG. 311.—The ethmoidal bone. Posterior aspect.



The *medial surface* of the labyrinth (fig. 313) forms part of the lateral wall of the corresponding nasal cavity; it consists of a thin lamella, which descends from the under surface of the lamina cribrosa, and ends in a free, convoluted portion, the *middle nasal concha*. The upper part of the medial surface is

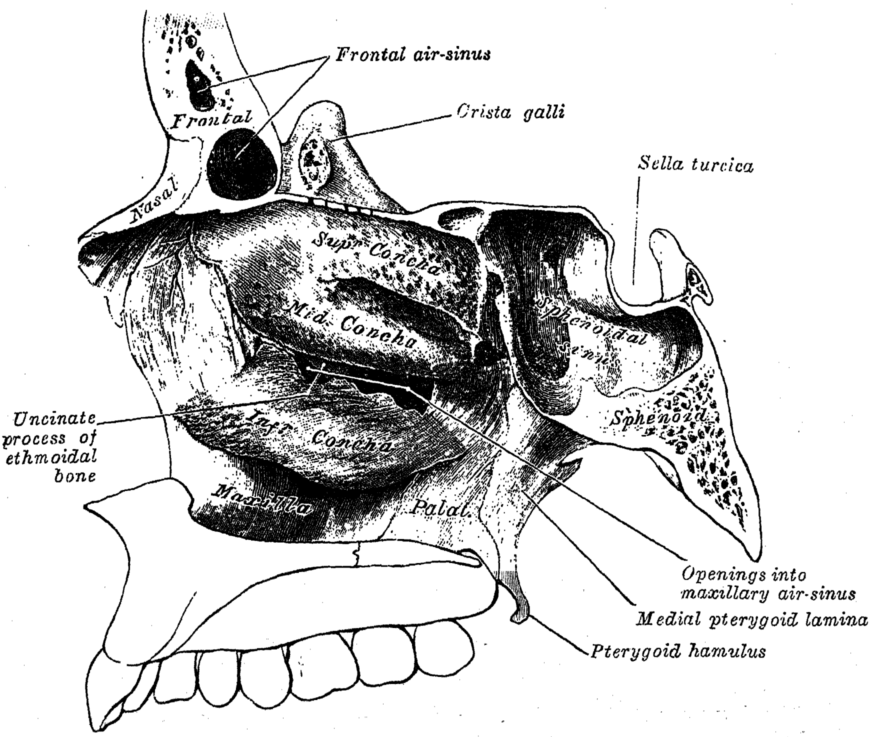
marked by numerous grooves, directed nearly vertically downwards from the lamina cribrosa; they lodge branches of the olfactory nerves, which are distributed to the mucous membrane covering the superior nasal concha. The

FIG. 312.—The ethmoidal bone. Right lateral aspect.



posterior part of the medial surface is subdivided by a narrow, oblique fissure, the *superior meatus* of the nose, which is bounded above by a thin, curved plate, the *superior nasal concha*; the posterior ethmoidal air-sinuses open into this meatus. Below and in front of the superior meatus, is the convex surface of the middle nasal concha; it extends along the whole length of the

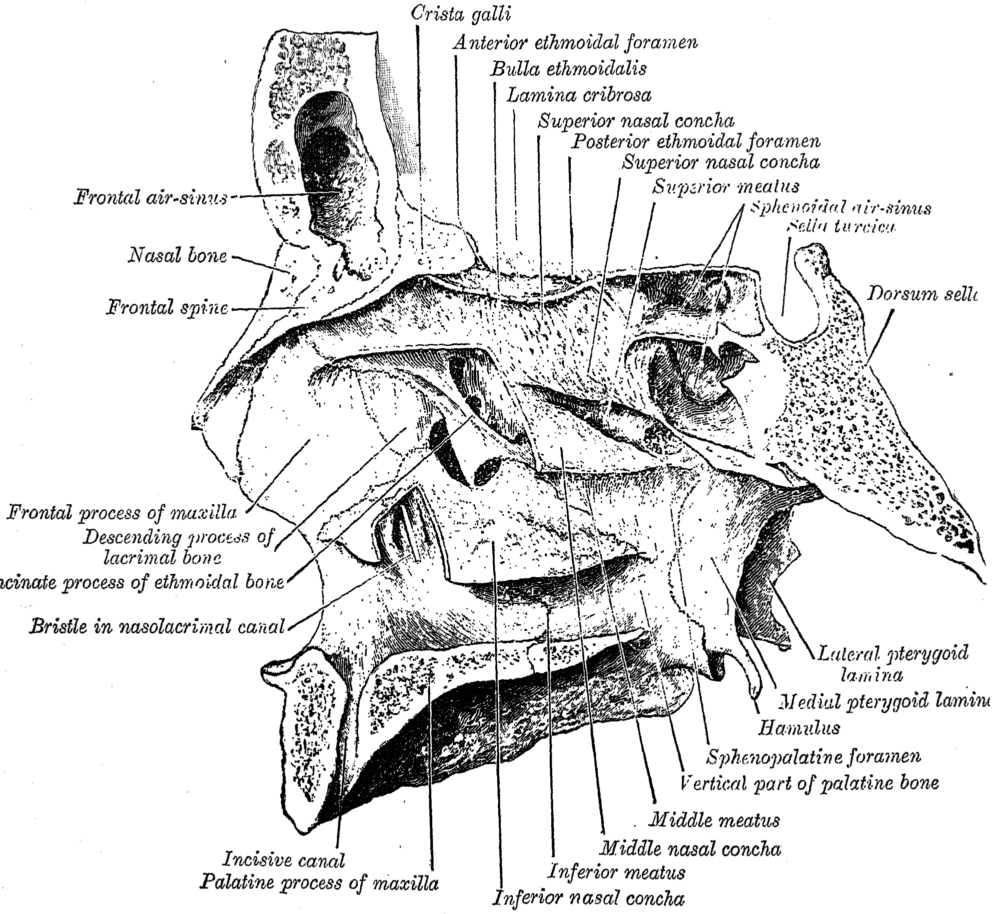
FIG. 313.—The lateral wall of the right nasal cavity, showing the ethmoidal bone (coloured red) and the inferior nasal concha (coloured blue) in position.



medial surface of the labyrinth. Its lower margin is free and thick, while its lateral surface is concave, and assists in forming the *middle meatus* of the nose. The middle ethmoidal air-sinuses produce a rounded swelling, named the

bulla ethmoidalis, on the lateral wall of the middle meatus (fig. 314); on this bulla, or immediately above it, these air-sinuses open into the meatus. A curved passage, named the *infundibulum*, extends upwards and forwards from the middle meatus; it communicates with the anterior ethmoidal air-sinuses, and in rather more than 50 per cent. of skulls is continued upwards as the fronto-nasal duct into the frontal air-sinus.

Fig. 314.—The lateral wall of the right nasal cavity, with parts of the middle and inferior nasal conchæ removed.



Ossification.—The ethmoidal bone is ossified in the cartilaginous nasal capsule from three centres; one for the lamina perpendicularis, and one for each labyrinth.

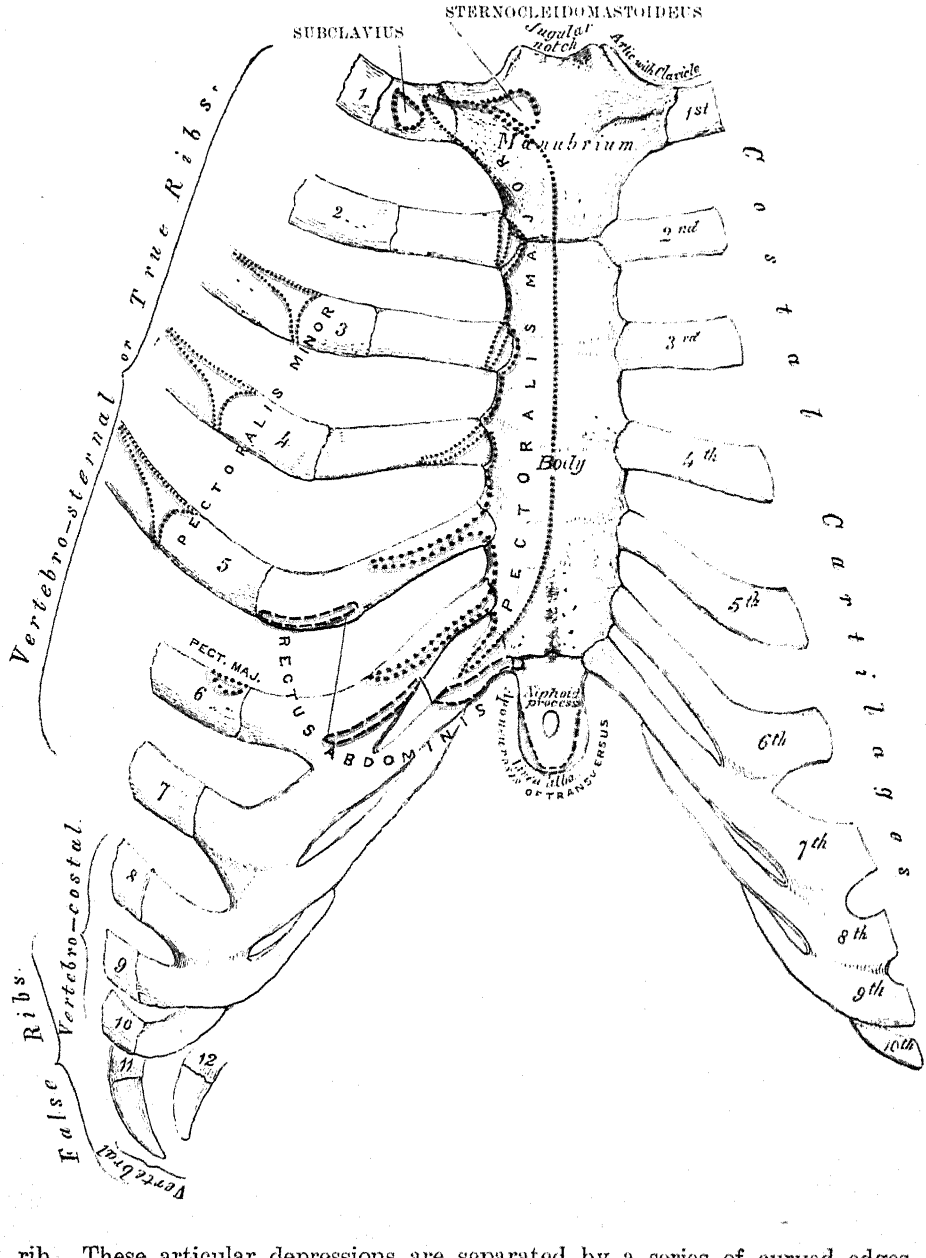
The centre for each labyrinth appears in the region of the lamina papyracea between the fourth and fifth months of fœtal life, and extends into the conchæ. At birth, the bone consists of the two labyrinths, which are small and ill-developed. During the first year after birth, the lamina perpendicularis and crista galli begin to ossify from a single centre, and are joined to the labyrinths about the beginning of the second year. The lamina cribrosa is ossified partly from the lamina perpendicularis and partly from the labyrinths. The ethmoidal cells begin to develop during fœtal life, and in the new-born infant have the form of narrow pouches.

The Inferior Nasal Conchæ (Conchæ Nasales Inferiores)

The **inferior nasal conchæ** are curved laminæ which extend horizontally along the lateral walls of the nasal cavities (fig. 313). Each bone has two surfaces, two borders, and two ends

similar one on the manubrium, forms a cavity for the reception of the sternal end of the cartilage of the second rib; below this are four angular facets which receive the sternal ends of the cartilages of the third, fourth, fifth, and sixth ribs; the inferior angle has a small facet, which, with a similar one on the xiphoid process, forms a notch for the reception of the cartilage of the seventh

FIG. 278.—The sternum and costal cartilages. Anterior aspect.

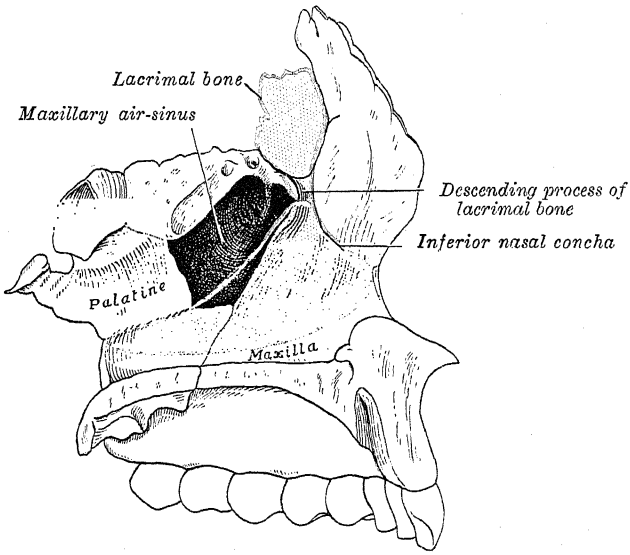


rib. These articular depressions are separated by a series of curved edges, which diminish in length from above downwards, and correspond to the anterior ends of the intercostal spaces.

It will be observed that most of the cartilages of the true ribs articulate with the sternum at the lines of junction of its primitive component segments; this is well seen in many of the lower animals, where the parts of the bone remain ununited longer than in man.

bony canal for the nasolacrimal duct; the lacrimal hamulus sometimes exists as a separate piece, and is then called the *lesser lacrimal bone.* On the *medial or nasal surface* is a vertical furrow, corresponding to the posterior lacrimal crest on the lateral surface. The area in front of this furrow forms part of the middle meatus of the nose; that behind the furrow articulates with the ethmoidal bone, and completes some of the anterior ethmoidal air-sinuses. The *anterior border* of the lacrimal bone articulates with the frontal process of the maxilla; the *posterior border* with the lamina papyracea of the ethmoidal bone; the *superior border* with the frontal bone. The posterior part of the *inferior border* articulates with the orbital plate of the maxilla.

Fig. 318.—A sketch showing how the medial wall of the nasolacrimal canal is completed by the articulation of the descending process of the lacrimal bone with the lacrimal process of the inferior nasal concha. (After Whitnall.)



Ossification.—The lacrimal bone is ossified from one centre, which appears about the twelfth week of fœtal life in the membrane covering the cartilaginous nasal capsule.

The Nasal Bones (Ossa Nasalia)

The **nasal bones** are two small oblong bones, varying in size and form in different individuals; they are placed side by side between the frontal processes of the maxillæ, and form, by their junction, 'the bridge' of the nose (figs. 319, 356).

Each nasal bone has two surfaces and four borders. The *external surface* (fig. 320) is concavo-convex from above downwards, and convex from side to side; it is covered by the Procerus and Compressor naris, and is perforated near its centre by a foramen, for the transmission of a small vein. The *internal surface* (fig. 321) is concave from side to side, and is traversed from above downwards by a groove, the *ethmoidal sulcus,* which lodges the anterior ethmoidal nerve. The *superior border,* thick and serrated, articulates with the nasal notch of the frontal bone. The *inferior border,* thin and notched, gives attachment to the lateral cartilage of the nose. The *lateral border* articulates with the frontal process of the maxilla. The *medial border,* thicker above than below, articulates with the opposite nasal bone, and is prolonged behind into a vertical crest which forms a small part of the septum of the nose, and articulates, from above downwards, with the frontal spine, the lamina perpendicularis of the ethmoidal bone, and the cartilage of the septum of the nose.

Ossification.—The nasal bone is ossified from one centre, which appears at the beginning of the third month of fœtal life in the membrane overlying the anterior part of the cartilaginous nasal capsule.

Fig. 319.—The articulation of the nasal and lacrimal bones with the maxilla. Left lateral aspect.

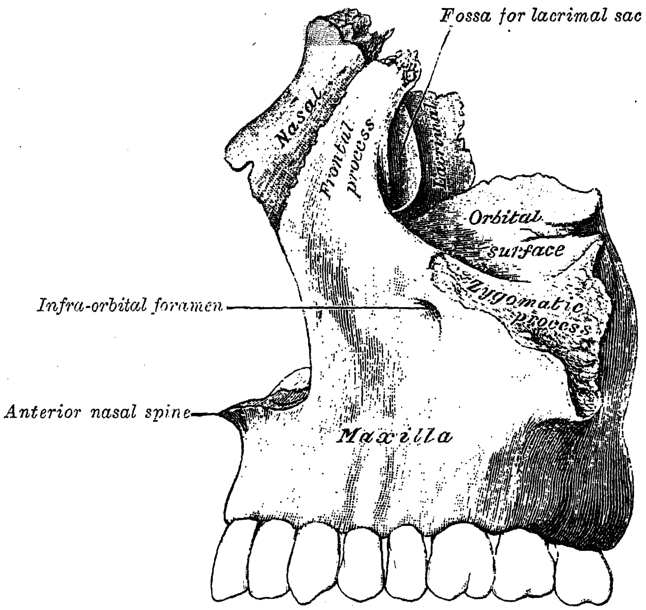


Fig. 320.—The right nasal bone. External aspect.

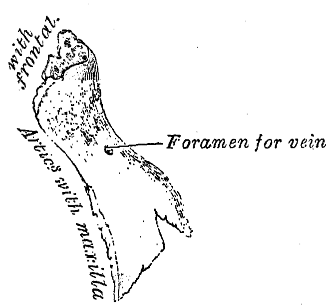
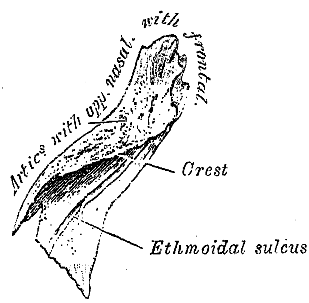


Fig. 321.—The right nasal bone. Internal aspect.



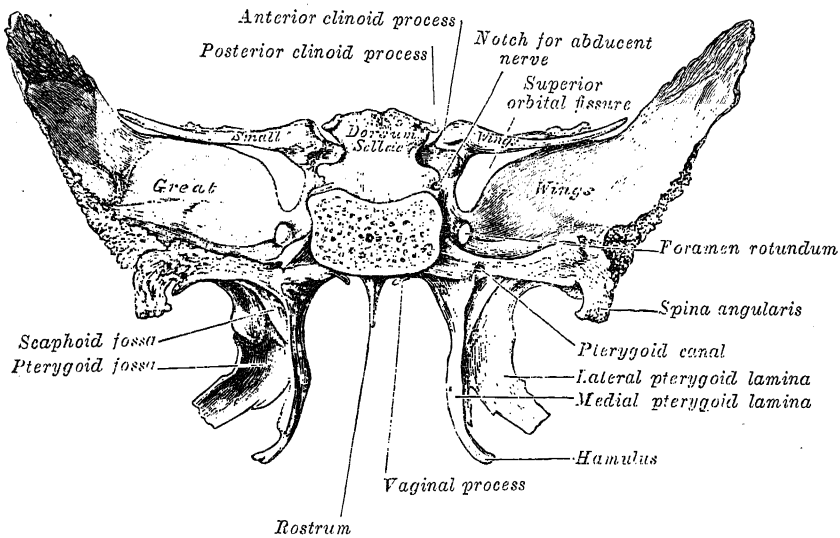
The Vomer

The **vomer** is thin, somewhat quadrilateral in shape, and forms the hinder and lower part of the septum of the nose (fig. 322) ; it has two surfaces and four borders. Each *surface* (fig. 323) is marked by small furrows for blood-vessels, and is traversed by the *nasopalatine groove* which runs obliquely downwards and forwards, and lodges the corresponding nasopalatine nerve and vessels. The *superior border*, the thickest, presents a deep furrow, bounded on either side by a projecting ala ; the furrow receives the rostrum of the sphenoidal bone ; the alæ articulate with the sphenoidal conchæ, the sphenoidal processes of the palatine bones and the vaginal processes of the medial pterygoid laminæ of the sphenoidal bone. The *inferior border* articulates with the nasal crest formed by the maxillæ and palatine bones. The *anterior border* is the longest ;

laterally by two small eminences, called the *middle clinoid processes*, whilst the posterior boundary is formed by a square plate of bone, the *dorsum sellæ*; the superior angles of this plate end in two tubercles, the *posterior clinoid processes*, which vary considerably in form and size, and give attachment to the lateral borders of the tentorium cerebelli. On either side of the dorsum sellæ is a notch for the passage of the abducent nerve, and below this notch a sharp process, the *petrosal process*, which articulates with the apex of the petrous portion of the temporal bone. Behind the dorsum sellæ is a shallow depression, which slopes obliquely backwards, and is continuous with the shallow groove on the superior surface of the basilar portion of the occipital bone; it supports the upper part of the pons.

The *lateral surfaces* of the body are united with the great wings and with the medial pterygoid laminæ. Above the attachment of each wing is a broad groove, the *carotid sulcus*, curved somewhat like the italic letter *f*; it lodges

FIG. 292.—The sphenoidal bone. Posterior aspect.



the internal carotid artery and the cavernous sinus. The carotid sulcus is deepest at its posterior end where it is overhung by the petrosal process, and limited laterally by a sharp margin called the *lingula*; the latter is continued backwards to overlie the posterior opening of the pterygoid canal.

The *posterior surface* of the body, quadrilateral in form (fig. 292), is joined, during infancy and adolescence, to the basilar part of the occipital bone by a plate of cartilage which ossifies between the eighteenth and twenty-fifth years.

The *anterior surface* of the body (fig. 293) presents, in the middle line, a triangular crest, the *sphenoidal crest*, which forms a small part of the septum of the nose. The anterior border of this crest articulates with the lamina perpendicularis of the ethmoidal bone; the lower border, with the vomer. On either side of the crest is an opening leading into the corresponding *sphenoidal air-sinus*.* The sphenoidal air-sinuses are two large, irregular cavities in the body of the bone, separated from one another by a bony septum, which is commonly bent to one or the other side. They vary considerably in form and size,† are seldom symmetrical, and are often partially subdivided by bony

* It may be stated here that the name 'sinus' is applied to two kinds of spaces associated with the skull, viz.: (*a*) 'blood-sinuses' which produce grooves on the inner surfaces of some of the bones, and (*b*) 'air-sinuses' which are cavities within some of the bones.

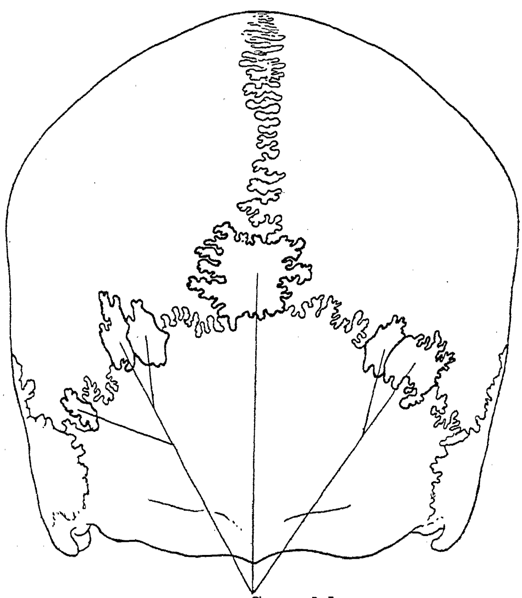
† Logan Turner (*The Accessory Sinuses of the Nose*, 1901) gives the following measurements for an adult sphenoidal sinus of average size: height, 2 cm.; breadth, 1·8 cm.; anteroposterior depth, 2·1 cm. Onodi (*The Accessory Sinuses of the Nose in Children*, 1911) states that in the new-born infant their height is 4 mm. and their width 2 mm., while at the eighth year of life their height is from 8 to 12 mm., and their width 11 mm.

cartilage of the septum of the nose is lodged. As growth proceeds, the union of the bony lamellæ extends upwards and forwards, and at the same time the intervening plate of cartilage undergoes absorption. By the age of puberty the lamellæ are almost completely united, but evidence of the bilaminar origin of the bone is seen in the everted alæ of its upper border and the groove on its anterior border. Up to a certain stage the vomer is entirely derived from membrane, but 'it becomes added to by the ossification of the hinder end of the anterior paraseptal cartilage.' * From this part of the ossified anterior paraseptal cartilage a plate of bone descends by the side of the primary part of the vomer, and fuses with it. The vomeronasal cartilage of Jacobson is the persistent part of the anterior paraseptal cartilage.*

THE SUTURAL BONES (OSSA SUTURARUM)

In addition to the usual centres of ossification of the cranial bones, others may occur in the course of the sutures, giving rise to irregular, isolated, *sutural or Wormian* † *bones* (fig. 325). They occur most frequently in the course of the lambdoid suture, but are occasionally seen at the fonticuli, especially the posterior. One, the *pterion ossicle*, sometimes exists between the sphenoidal angle of the parietal bone and the great wing of the sphenoidal bone. They have a tendency to be more or less symmetrical on the two sides of the skull, and vary much in size. Their number is generally limited to two or three; but more than a hundred have been found in the skull of a hydrocephalic subject.

FIG. 325.—A sketch showing sutural bones in the lambdoid and sagittal sutures.



Sutural bones

Applied Anatomy.—An arrest in the ossifying process may give rise to deficiencies, gaps, or fissures in the cranium, which are of importance from a medico-legal point of view, as they are liable to be mistaken for fractures. The fissures generally extend from the margins towards the centre of a bone, but the gaps may be found in the middle as well as at the edges. In course of time they may become filled with thin laminæ of bone. In some instances, however, the gaps are due to absorption of bone already formed. This is especially so when they appear in the centre of a bone such as the parietal, the ossification of which has already been described as occurring in a regular manner radiating from two centres. The condition is most commonly seen in very badly nourished children affected with congenital syphilis, and is called *craniotabes*.

* E. Fawcett, *Journal of Anatomy and Physiology*, vol. xlv.

† Ole Worm, Professor of Anatomy at Copenhagen, 1624-1639, was erroneously supposed to have given the first detailed description of these bones.

THE FACIAL BONES (OSSA FACIEI)

The Maxillæ

The **maxillæ** are the largest bones of the face, excepting the mandible, and form, by their union, the whole of the upper jaw (fig. 356). Each assists in completing the roof of the mouth, the floor and lateral wall of the nose, and the floor of the orbit; it also enters into the formation of the infratemporal and pterygopalatine fossæ, and the inferior orbital and pterygomaxillary fissures.

Each maxilla consists of a body and four processes—zygomatic, frontal, alveolar, and palatine.

The **body** of the maxilla is somewhat pyramidal in shape. It has four surfaces,—anterior, infratemporal, orbital, and nasal—and encloses a large cavity, the maxillary air-sinus or antrum of Highmore.

The *anterior surface* (fig. 326) is directed forwards and lateralwards. On its lower part is a series of eminences (juga alveolaria) corresponding to the positions of the roots of the upper teeth. Just above those of the incisor teeth is a depression, the *incisive fossa*, which gives origin to the Depressor septi; to the alveolar border below the fossa a slip of the Orbicularis oris is attached; above and lateral to the fossa, the Nasalis arises. Lateral to the incisive fossa is a larger and deeper depression, the *canine fossa*; it is separated from the incisive fossa by the *canine eminence*, which corresponds to the socket of the canine tooth; the fossa gives origin to the Caninus. Above the canine fossa is the *infra-orbital foramen*, the end of the infra-orbital canal; it transmits the infra-orbital vessels and nerve. Above the foramen is a sharp border marking the junction of the anterior and orbital surfaces. This border forms a small part of the circumference of the base of the orbit, and gives origin to the orbital head of the Quadratus labii superioris. Medially, the anterior surface is limited by a deep concavity, the *nasal notch*; the margin of the notch gives attachment to the Dilatator naris posterior, and ends below in a pointed process which with the corresponding process of the opposite maxilla forms the *anterior nasal spine*.

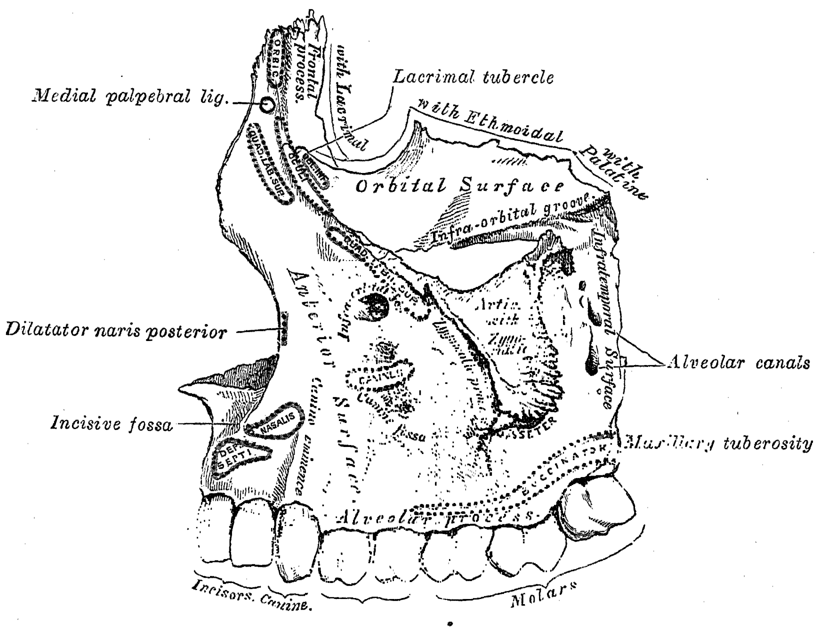
The *infratemporal surface* (fig. 326) is convex, directed backwards and lateralwards, and forms the anterior wall of the infratemporal fossa. It is separated from the anterior surface by the zygomatic process and by a ridge which runs upwards to that process from the socket of the first molar tooth. It is pierced near its centre by the apertures of two or three *alveolar canals*, which transmit the posterior superior alveolar vessels and nerves. At the lower part of this surface is a round eminence, the *maxillary tuberosity*, which is rough for articulation with the pyramidal process of the palatine bone (fig. 328); it gives origin to a few fibres of the Pterygoideus internus, and in some cases articulates with the lateral pterygoid lamina of the sphenoidal bone. Above this is a smooth surface, which forms the anterior boundary of the pterygopalatine fossa, and is grooved for the maxillary nerve; the groove for this nerve is directed lateralwards and slightly upwards, and is continuous with the infra-orbital groove on the orbital surface.

The *orbital surface* (fig. 326) is smooth and triangular, and forms the greater part of the floor of the orbit. Its *medial border* presents anteriorly a notch, the *lacrimal notch*, behind which it articulates from before backwards with the lacrimal bone, the lamina papyracea of the ethmoidal bone, and the orbital process of the palatine bone (fig. 328). Its *posterior border* is smooth and rounded; it forms the lateral part of the lower margin of the inferior orbital fissure, and its central part is notched by the commencement of the infra-orbital groove. The *anterior border* forms a small part of the circumference of the base of the orbit, and is continuous medially with the anterior lacrimal crest on the frontal process (p. 232). The *infra-orbital groove*, for the passage of the infra-orbital vessels and nerve, begins at the middle of the posterior border, where it is continuous with the groove near the upper edge of the infra-

temporal surface; it passes forwards and ends in the *infra-orbital canal*, which opens on the anterior surface of the bone just below the margin of the orbit. At the medial and front part of the orbital surface, and lateral to the lacrimal groove, is a small depression, which gives origin to the Obliquus oculi inferior.

The *nasal surface* (fig. 327) presents in its upper and posterior part a large, irregular opening leading into the maxillary air-sinus. At the upper border of this aperture are some broken air-sinuses, which, in the articulated skull, are closed by the ethmoidal and lacrimal bones. Below the opening into the maxillary air-sinus is a smooth concave surface which forms part of the inferior meatus of the nasal cavity, and behind it is a rough surface for articulation with the vertical part of the palatine bone; this rough surface is traversed by a groove, which begins near the middle of the posterior border, runs obliquely downwards and forwards, and is converted into the *pterygopalatine canal* by the vertical part of the palatine bone and the pterygoid process of the sphenoidal

FIG. 326.—The left maxilla. Lateral aspect.

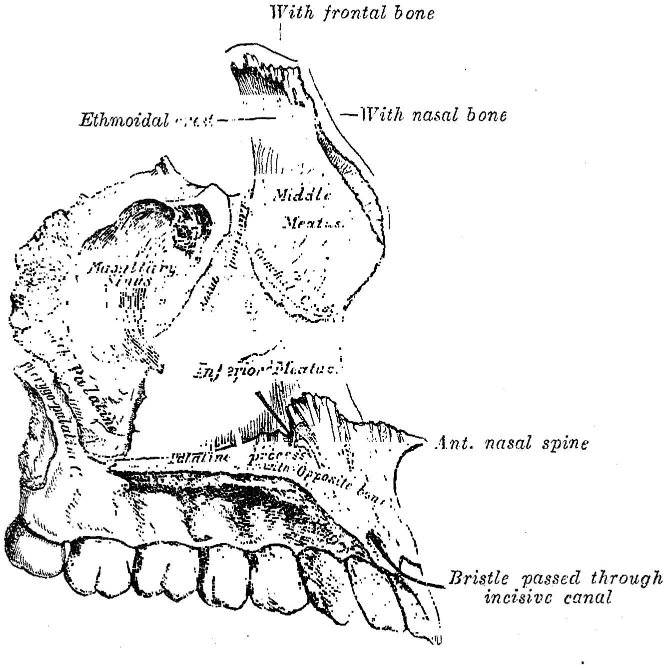


bone. In front of the opening of the maxillary air-sinus is a deep groove, the *sulcus lacrimalis*, which constitutes about two-thirds of the circumference of the nasolacrimal canal, the remaining one-third being formed by the descending process of the lacrimal bone and the lacrimal process of the inferior nasal concha (fig. 318); this canal opens into the inferior meatus of the nose (fig. 314) and transmits the nasolacrimal duct. More anteriorly is an oblique ridge, the *crista conchalis*, for articulation with the inferior nasal concha. The shallow concavity below this ridge forms part of the inferior meatus of the nose, and the surface above the ridge part of the atrium of the middle meatus.

The **maxillary air-sinus** (*antrum of Highmore*) is a large pyramidal cavity within the body of the maxilla. Its walls are thin, and correspond to the nasal, orbital, anterior, and infratemporal surfaces of the body of the bone. Its *apex*, directed lateralwards, is formed by the zygomatic process; its *base*, or nasal wall, directed medialwards, is formed by the lateral wall of the nose, and presents, in the disarticulated bone, a large, irregular aperture communicating with the nasal cavity. In the articulated skull this aperture is much reduced in size by the following bones: the uncinate process of the ethmoidal bone and the descending process of the lacrimal bone above, the maxillary process of the inferior nasal concha below, and the vertical part of the palatine bone behind (figs. 314, 328). The maxillary air-sinus communicates with

the middle meatus of the nose, generally by two small apertures, one of which is usually closed, in the recent state, by mucous membrane. On the *posterior wall* are the *alveolar canals*, transmitting the posterior superior alveolar vessels and nerves to the molar teeth ; these canals occasionally project as ridges into the maxillary air-sinus. The *floor* is formed by the alveolar process of the maxilla, and its lowest part is usually about 1·25 cm. below the level of the floor of the nasal cavity. In a large proportion of cases radiating septa of varying sizes spring from the floor of the sinus in the intervals between adjacent teeth ; in some cases the floor is perforated by the fangs of the molar teeth.* The infra-orbital canal usually projects into the sinus as a well-marked ridge extending from the *roof* to the *anterior wall.* The size of the cavity varies in different skulls, and even on the two sides of the same skull.†

Fig. 327.—The left maxilla. Medial aspect.



Applied Anatomy.—The extreme thinness of the walls of this cavity affords an explanation of the fact that a tumour growing from the maxillary air-sinus and encroaching upon the adjacent parts may push up the floor of the orbit, and displace the eyeball; may project into the nose; may protrude forwards on to the cheek; or may make its way backwards into the infratemporal fossa, or downwards into the mouth.

The **zygomatic process** of the maxilla is a rough triangular eminence, situated at the angle of separation of the anterior, infratemporal, and orbital surfaces. In front it forms part of the anterior surface of the body of the bone ; *behind*, it is concave, and continuous with the infratemporal surface ; *above*, it is rough and serrated for articulation with the zygomatic bone ; *below*, it presents a prominent arched border which separates the anterior from the infratemporal surface.

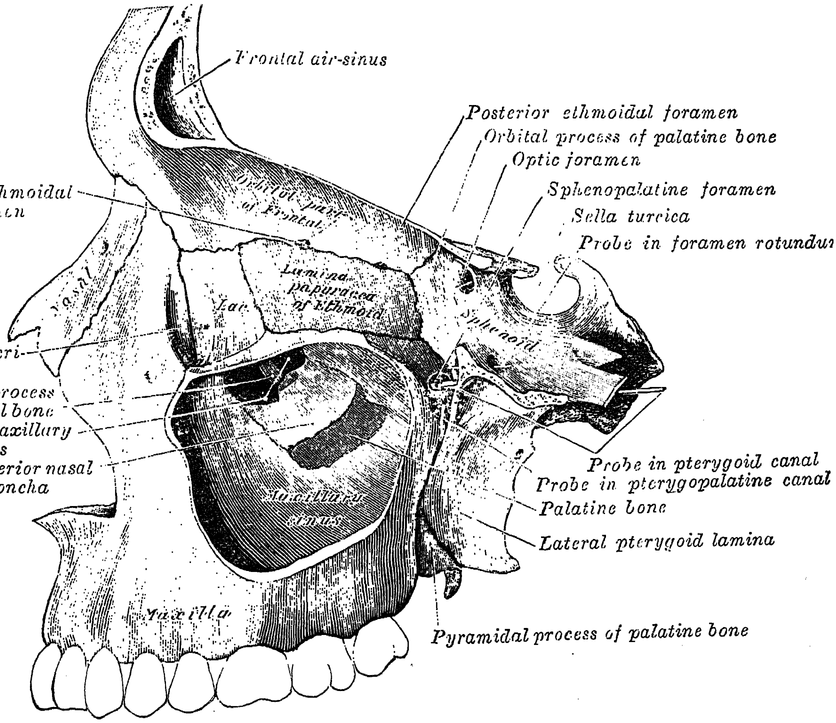
The **frontal process** of the maxilla projects upwards and backwards between the nasal and lacrimal bones (figs. 328, 353). Its *lateral surface* is divided into two parts by a vertical crest, the *anterior lacrimal crest*, which gives attachment

* The number of teeth whose roots are in relation with the floor of the maxillary air-sinus is variable. The sinus may extend so as to be in relation to all the teeth of the true maxilla, from the canine to the third molar.—(Salter.)

† Logan Turner (*op. cit.*) gives the following measurements for an adult sinus of average size : vertical height opposite first molar tooth, 3·5 cm. ; transverse breadth, 2·5 cm. ; and antero-posterior depth, 3·2 cm.

to the medial palpebral ligament, and is continuous below with the infra-orbital margin. At the junction of the crest with the orbital surface is a small tubercle, the *lacrimal tubercle,* which serves as a guide to the position of the lacrimal sac. The part in front of the anterior lacrimal crest is smooth, and merges below with the anterior surface of the body; it gives attachment to a portion of the Orbicularis oculi, and to the angular head of the Quadratus labii superioris. The part behind the anterior lacrimal crest is hollowed into a groove which is continuous inferiorly with the sulcus lacrimalis on the nasal surface of the bone, and posteriorly, in the articulated skull, with the lacrimal groove on the lacrimal bone, the two grooves forming the *lacrimal fossa* for the lodgement of the lacrimal sac.

Fig. 328.—The left maxillary air-sinus. Opened from the lateral side.

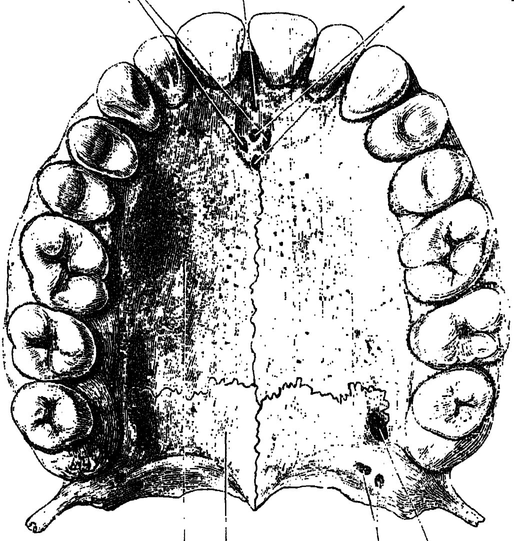


The *medial surface* of the frontal process forms a portion of the lateral wall of the nasal cavity. A rough, uneven area at its upper part articulates with the ethmoidal bone and closes in the anterior ethmoidal air-sinuses. Below this rough area is an oblique ridge, the *crista ethmoidalis*, the posterior part of which articulates with the middle nasal concha, while the anterior part is termed the *agger nasi*; the crista ethmoidalis forms the upper limit of the atrium of the middle meatus of the nose. The *upper end* of the frontal process articulates with the nasal notch of the frontal bone, the *anterior border* with the nasal bone, and the *posterior border* with the lacrimal bone.

The **alveolar process** of the maxilla, thick and arched, is broader behind than in front, and excavated into cavities or alveoli for the reception of the roots of the teeth. These cavities are eight in number, and vary in size and depth according to the teeth they contain. That for the canine tooth is the deepest; those for the molars are the widest, and are subdivided into three minor cavities by septa; those for the incisors and the second bicuspid are single; that for the first bicuspid is sometimes divided into two. The Buccinator arises from the outer surface of this process, as far forward as the first molar tooth. When the maxillæ are articulated with each other, their alveolar processes together form the *alveolar arch.*

The **palatine process** of the maxilla, thick and strong, is horizontal and projects medialwards from the nasal surface of the bone. It forms a considerable part of the floor of the nose and the roof of the mouth, and is much thicker in front than behind. Its *inferior surface* (fig. 329), concave, rough and uneven, forms, with the palatine process of the opposite bone, the anterior three-fourths of the hard palate. It is perforated by numerous foramina for the passage of the nutrient vessels, and presents depressions for the lodgement of the palatine glands; it is channelled at the posterior part of its lateral border by two grooves which lodge the descending palatine vessels, and the anterior palatine nerve. When the two maxillæ are articulated, a funnel-shaped opening, the *incisive foramen*, is seen in the middle line, immediately behind the incisor teeth.

Fig. 329.—The bony palate and the alveolar arch. Inferior aspect.



In this opening the orifices of two lateral canals are visible; they are named the *incisive canals* or *foramina of Stensen*; each leads upwards into the corresponding nasal cavity and transmits the terminal branch of the greater palatine artery and the nasopalatine nerve. Occasionally there are two additional apertures in the middle line; they are termed the *foramina of Scarpa*, and when present transmit the nasopalatine nerves, the left passing through the anterior, and the right through the posterior foramen. On the under surface of the palatine process, a delicate suture, well seen in young skulls, may sometimes be noticed extending lateralwards and forwards from the incisive foramen to the interval between the lateral incisor and the canine teeth. The small part in front of this suture constitutes the *premaxilla* or *os incisivum*, which in most vertebrates forms an independent bone; it includes the whole thickness of the alveolus, the corresponding part of the floor of the nose and the anterior nasal spine, and contains the sockets of the incisor teeth. The *upper surface* of the palatine process is concave from side to side, smooth, and forms the greater part of the floor of the nasal cavity; close to the anterior part of its medial margin is the upper orifice of the incisive canal. The *lateral border* of the process is fused with the rest of the bone. The *medial border*, thicker in front than behind, is raised into a ridge, the *nasal crest*, which, with the

corresponding ridge of the opposite bone, forms a groove for the reception of the vomer. The front part of this ridge rises to a considerable height, and is named the *incisor crest* (fig. 327) ; it is prolonged forwards into a sharp process, which, with the similar process of the opposite bone, forms the *anterior nasal spine*. The *posterior border* is serrated for articulation with the horizontal part of the palatine bone.

Ossification.—The maxilla is mainly developed in membrane. Mall * and Fawcett † have shown that it is ossified from two centres, one for the maxilla proper and one for the premaxilla. These centres appear at the end of the sixth week of fœtal life, that for the maxilla proper commencing above the canine tooth-germ ;

FIG. 330.—The right maxilla at birth. Lateral aspect.

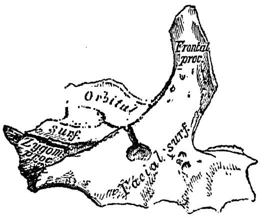


FIG. 331.—The right maxilla at birth. Inferior aspect.

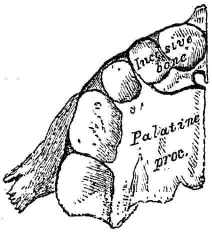
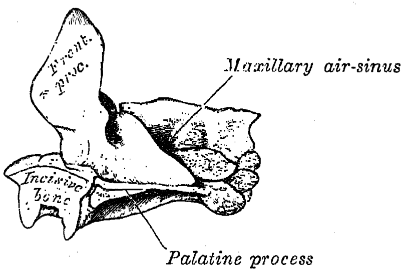


FIG. 332.—The right maxilla at birth. Medial aspect.



they unite at the end of the second or early in the third month, but the suture between them (fig. 331) may persist on the palate until nearly middle life ; the frontal process of the bone is developed from both centres. The ossifying maxilla invades and incorporates the paranasal process of the cartilaginous nasal capsule, a condition which may account for the small islands of cartilage which are sometimes found in the ossifying maxilla. The maxillary air-sinus appears as a shallow groove (fig. 332) on the nasal surface of the bone about the fourth month of fœtal life, but does not reach its full size until after the second dentition. The infra-orbital vessels and nerve lie for a time in an open groove in the floor of the orbit ; the anterior part of this groove is converted into the infra-orbital canal by a lamina of bone which grows from the lateral side of the groove.

Changes produced in the Maxilla by Age

At birth the transverse and anteroposterior diameters of the maxilla are each greater than the vertical. The frontal process is well-marked, but the body of the bone consists of little more than the alveolar process, the tooth-sockets reaching almost to the floor of the orbit. The maxillary air-sinus is seen as a furrow on the lateral wall of the nose. In the adult the vertical diameter is the greatest, owing to the development of the alveolar process and the increase in size of the air-sinus. In old age, the bone reverts in some measure to the infantile condition : its height is diminished, and after the loss of the teeth the alveolar process is absorbed, and the lower part of the bone contracted and reduced in thickness.

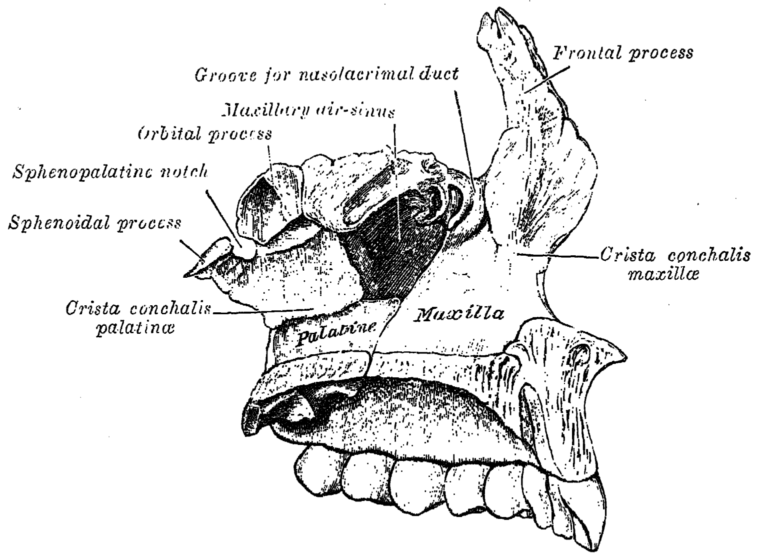
* *American Journal of Anatomy*, vol. v. 1906.

† *Journal of Anatomy and Physiology*, vol. xlv. 1911.

The Palatine Bones (Ossa Palatina)

The **palatine bones** are situated at the posterior part of the nasal cavity, between the maxillæ and the pterygoid processes of the sphenoidal bone (fig. 333).

Fig. 333.—The articulation of the left palatine bone with the left maxilla.



Each assists in forming the floor and lateral wall of the nasal cavity, the roof of the mouth, and the floor of the orbit; it enters into the formation of the pterygopalatine and pterygoid fossæ and the inferior orbital fissure.

The palatine bone somewhat resembles the letter L, and consists of a horizontal and a vertical part, and three outstanding processes—viz. the pyramidal process, which is directed backwards, lateralwards, and downwards, from the junction of the horizontal and vertical parts, and the orbital and sphenoidal processes, which surmount the vertical part, and are separated by a deep notch, the sphenopalatine notch.

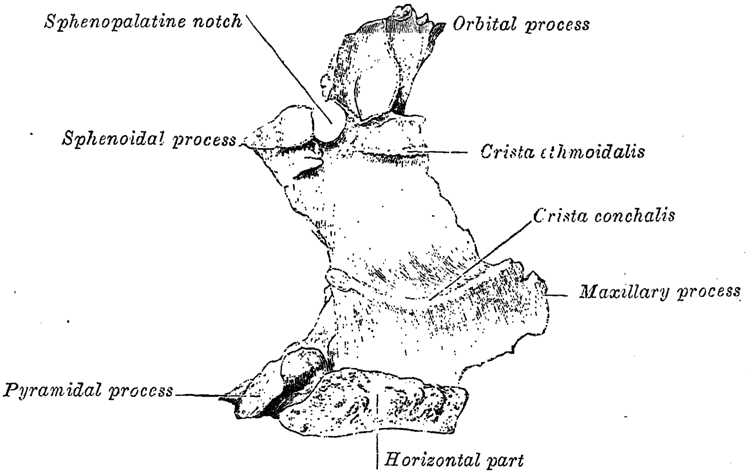
The **horizontal part** of the palatine bone (figs. 334, 335) is quadrilateral, and has two surfaces and four borders. The *nasal surface*, concave from side to side, forms the posterior part of the floor of the nasal cavity. The *palatine surface* forms, with the corresponding surface of the opposite bone, the posterior one-fourth of the hard palate; near its posterior margin is a curved ridge. The *posterior border* is thin and concave; to it, and to the palatine surface as far forwards as the curved ridge just mentioned, the expanded tendon of the Tensor veli palatini is attached. The medial end of the posterior border is pointed, and, when united with that of the opposite bone, forms a projecting process, the *posterior nasal spine*, for the attachment of the Musculus uvulæ. The *anterior border* is serrated, and articulates with the palatine process of the maxilla. The *lateral border* is united with the inferior border of the vertical part, and is grooved by the lower end of the pterygopalatine sulcus. The *medial border* thick and serrated, articulates with the corresponding border of the opposite bone, and the opposed borders form a crest which articulates with the posterior part of the lower edge of the vomer, and is continuous anteriorly with the nasal crest of the maxillæ.

The **vertical part** of the palatine bone (figs. 334, 335), thin and of an oblong form, has two surfaces and four borders.

The *nasal surface* exhibits at its lower part a broad, shallow depression which forms part of the inferior meatus of the nasal cavity. Immediately

above this is a horizontal ridge, the *crista conchalis*, for articulation with the inferior nasal concha ; still higher is a second broad, shallow depression, which forms part of the middle meatus, and is limited above by the *crista ethmoidalis*,

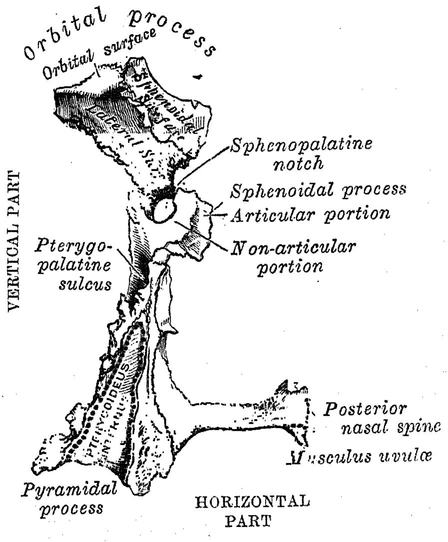
FIG. 334.—The left palatine bone. Medial aspect. (Enlarged.)



for articulation with the middle nasal concha. Above the crista ethmoidalis is a narrow, horizontal groove, which forms part of the superior meatus.

The *maxillary surface* is rough and irregular throughout the greater part of its extent, for articulation with the nasal surface of the maxilla ; its upper and posterior part is smooth and forms the medial wall of the pterygopalatine fossa ; its front portion is also smooth and forms the posterior part of the medial wall of the maxillary air-sinus (fig. 328). On the posterior part of the maxillary surface is a deep vertical groove, the *pterygopalatine sulcus*, which in the articulated skull is converted into the *pterygopalatine canal* by the maxilla and the pterygoid process of the sphenoidal bone ; this canal transmits the descending palatine vessels, and the palatine nerves.

FIG. 335.—The left palatine bone. Posterior aspect. (Enlarged.)



The *anterior border* is thin and irregular ; at the level of the crista conchalis is a pointed projecting lamina, the *maxillary process*, which is directed forwards below and behind the maxillary process of the inferior nasal concha with which it articulates and assists in forming the medial wall of the maxillary air-sinus (fig. 328). The *posterior border* (fig. 335) is serrated for articulation with the medial pterygoid lamina of the sphenoidal bone. This border is continuous above with the sphenoidal process ; it expands below into the pyramidal process. The *superior border* supports the orbital process in front and the sphenoidal process behind. These processes are separated by the *sphenopalatine notch*, which is converted into the *sphenopalatine foramen* by the under surface of the body of the sphenoidal bone. In the articulated skull this foramen leads from the pterygopalatine fossa into the

posterior part of the superior meatus of the nose, and transmits the spheno palatine vessels and the posterior superior nasal nerves. The *inferior border* is fused with the lateral border of the horizontal part, and in front of the pyramidal process is grooved by the lower end of the pterygopalatine sulcus.

The **pyramidal process** (tuberosity) of the palatine bone projects backwards, lateralwards, and downwards from the junction of the horizontal and vertical parts of the bone, and fits into the angular interval between the lower ends of the pterygoid laminæ. On its *posterior surface* is a smooth, grooved, triangular area, limited on either side by a rough articular furrow. The furrows articulate with the pterygoid laminæ, while the grooved triangular area completes the lower part of the pterygoid fossa and gives origin to some fibres of the Pterygoideus internus. The anterior part of the *lateral surface* is rough for articulation with the maxillary tuberosity; the posterior part consists of a smooth triangular area which appears, in the articulated skull, at the lower part of the infratemporal fossa between the maxillary tuberosity and the lateral pterygoid lamina (fig. 328). In the *base* or *inferior surface* of the pyramidal process, close to its union with the horizontal part of the bone, are the *lesser palatine foramina* for the transmission of the middle and posterior palatine nerves (fig. 329).

The **orbital process** of the palatine bone (figs. 334, 335) is directed upwards and lateralwards from the front of the vertical part, to which it is joined by a constricted neck. It encloses an air-sinus, and presents three articular and two non-articular surfaces. The articular surfaces are: (1) the *anterior* or *maxillary*, of an oblong form, is directed forwards, lateralwards, and downwards, and articulates with the maxilla; (2) the *posterior* or *sphenoidal*, directed backwards, upwards, and medialwards, presents the opening of the air-sinus, which usually communicates with the sphenoidal air-sinus; the margins of the opening articulate with the sphenoidal concha; (3) the *medial* or *ethmoidal*, directed medialwards and forwards, articulates with the labyrinth of the ethmoidal bone. In some cases, the air-sinus opens on this surface and then communicates with the posterior ethmoidal air-sinuses; more rarely it opens on the ethmoidal and sphenoidal surfaces, and then communicates with the posterior ethmoidal air-sinuses, and the sphenoidal air-sinus. The non-articular surfaces are: (1) the *superior* or *orbital*, triangular in shape, is directed upwards and lateralwards, and forms the posterior part of the floor of the orbit; and (2) the *lateral*, of an oblong form, is directed towards the pterygopalatine fossa, and is separated from the orbital surface by a rounded border, which forms the medial part of the lower margin of the inferior orbital fissure; on the lower part of this surface is a groove, directed lateralwards and upwards, which lodges the maxillary nerve and is continuous with the transverse groove on the upper part of the infratemporal surface of the maxilla (p. 230). The border between the lateral and posterior surfaces is prolonged downwards as the anterior boundary of the sphenopalatine notch.

The **sphenoidal process** of the palatine bone (figs. 334, 335) is a thin, compressed plate, smaller and on a lower level than the orbital process; it is directed upwards and medialwards. Its *superior surface* articulates with the under surface of the sphenoidal concha and the root of the medial pterygoid lamina; it presents a groove which contributes to the formation of the pharyngeal canal. The *inferomedial surface* is concave, and forms a small part of the roof and lateral wall of the nasal cavity. The posterior part of the *lateral surface* articulates with the medial pterygoid lamina; the anterior part is smooth, and forms a portion of the medial wall of the pterygopalatine fossa. The *posterior border* is rough and articulates with the vaginal process of the medial pterygoid lamina. The *anterior border* forms the posterior boundary of the sphenopalatine notch. The *medial border* articulates with the ala of the vomer.

The orbital and sphenoidal processes are separated from one another by the *sphenopalatine notch* which is converted into the sphenopalatine foramen by the under surface of the body of the sphenoidal bone; sometimes the two processes are united by a spicule of bone which converts the notch into a foramen.

Ossification.—The palatine bone is ossified in membrane from one centre, which appears during the eighth week of fœtal life in the vertical part of the bone.

From this point ossification spreads upwards into the orbital and sphenoidal processes, medialwards into the horizontal part, and downwards into the pyramidal process.

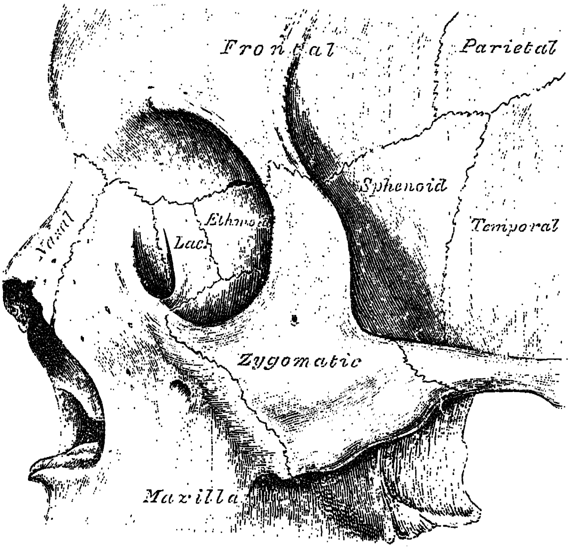
At the time of birth the height of the vertical part is about equal to the transverse width of the horizontal part, whereas in the adult it measures nearly twice as much.

The Zygomatic Bones (Ossa Zygomatica)

The **zygomatic or malar bones** are situated at the upper and lateral parts of the face. Each forms the prominence of the cheek, part of the lateral wall and floor of the orbit, and parts of the temporal and infratemporal fossæ (fig. 336).

The zygomatic bone is quadrangular in shape and has two surfaces, four borders, and four processes.

Fig. 336.—The left zygomatic bone *in situ*.



The *malar surface* (figs. 336, 337), directed lateralwards and forwards, is convex and is perforated near its orbital border by the *zygomaticofacial foramen* for the passage of the zygomaticofacial nerve and vessels; below this foramen is a slight elevation, which gives origin to the Zygomaticus. The *temporal surface* (fig. 338), directed medialwards and backwards, is concave, presenting anteriorly a rough, triangular area, for articulation with the maxilla, and posteriorly a smooth, concave surface, the upper part of which forms the anterior boundary of the temporal fossa, the lower, a part of the infratemporal fossa. Near the posterior edge of the rough triangular area is the *zygomaticotemporal foramen* for the transmission of the zygomaticotemporal nerve.

The *anterosuperior or orbital border* is smooth, concave, and forms a considerable part of the circumference of the base of the orbit. The *antero-inferior or maxillary border* is rough, and articulates with the maxilla; near the orbital margin it gives origin to the zygomatic head of the Quadratus labii superioris. The *posterosuperior or temporal border*, curved like an italic letter *f*, is continuous above with the temporal line on the frontal bone, and below with the upper border of the zygomatic arch; the temporal fascia is attached to it. The *postero-inferior or zygomatic border* affords attachment by its rough edge to the Masseter.

The *frontosphenoidal process* is thick and serrated, and articulates with the zygomatic process of the frontal bone. On its orbital surface, just within the

orbital margin and about 11 mm. below the zygomaticofrontal suture is a tubercle of varying size and form, but present in 95 per cent. of skulls (Whitnall).*

The *orbital process* is a thick, strong plate, projecting backwards and medialwards from the orbital margin. Its *orbital surface*, smooth and concave, forms a part of the floor and lateral wall of the orbit. On it are usually seen the orifices of two canals, the *zygomatico-orbital foramina* ; one of these canals opens on the temporal surface, the other on the malar surface of the bone ; the former transmits the zygomaticotemporal, the latter the zygomaticofacial nerve. Its *temporal surface*, smooth and convex, forms parts of the

Fig. 337.—The left zygomatic bone. Lateral aspect.

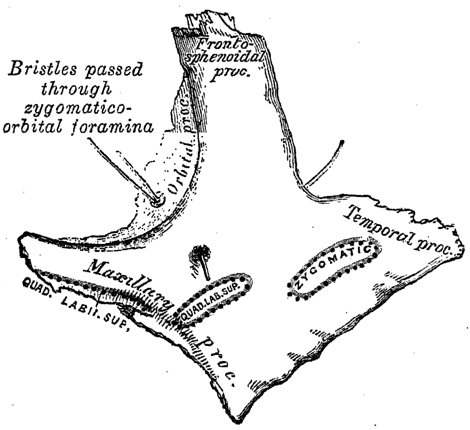
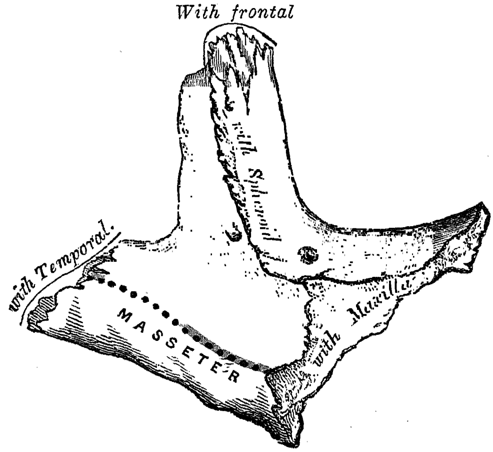


Fig. 338.—The left zygomatic bone. Medial aspect.



temporal and infratemporal fossæ. Its *anterior margin*, smooth and rounded, is part of the circumference of the base of the orbit. Its *superior margin*, rough, and directed horizontally, articulates with the frontal bone behind the zygomatic process. Its *posterior margin* is serrated for articulation with the great wing of the sphenoidal bone above, and the orbital surface of the maxilla below. Between these two serrated portions there is usually a short, concave, non-articular part which forms the anterior boundary of the inferior orbital fissure. This non-articular part is sometimes absent, and the fissure is then completed by the junction of the maxilla and the sphenoidal bone, or by the interposition of a small sutural bone in the angular interval between them.

The *infra-orbital process* is pointed and articulates with the maxilla, above the infra-orbital foramen.

The *temporal process* is directed backwards and ends in an oblique, serrated margin which articulates with the zygomatic process of the temporal bone.

Ossification.—The zygomatic bone is ossified from one centre which appears about the eighth week of fœtal life. The bone is sometimes divided by a horizontal suture into an upper larger, and a lower smaller division.

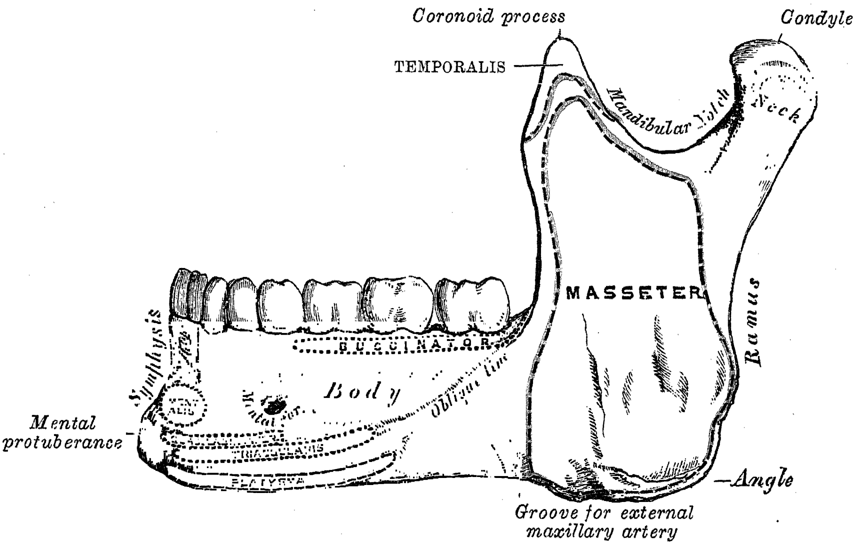
The Mandible (Mandibula)

The **mandible**, the largest and strongest bone of the face, consists of a curved, horizontal portion, the *body*, from the ends of which two perpendicular portions, the *rami*, project upwards.

* S. E. Whitnall, *The Anatomy of the Human Orbit*, 1921.—The structures attached to this tubercle are : (1) the "check ligament" of the Rectus lateralis ; (2) part of the aponeurosis of the Levator palpebræ superioris ; (3) the suspensory ligament of the eyeball ; and (4) the lateral palpebral ligament.

The **body** of the mandible is curved somewhat like a horseshoe, and has two surfaces and two borders. The *external surface* (fig. 339) is marked in the upper part of the median line by a faint ridge, indicating the *symphysis* or junction of the two pieces of which the bone is composed at an early period of life. This ridge divides below and encloses a triangular eminence, the *mental protuberance*, the base of which is depressed in the centre but raised on either side to form the *mental tubercle*. On either side of the ridge, just below the incisor teeth, is the *incisive fossa*, which gives origin to the Mentalis and to a small portion of the Orbicularis oris. Below the second premolar tooth, and about midway between the upper and lower borders of the body, is the *mental foramen*, for

Fig. 339.—The left half of the mandible. Lateral aspect.



the exit of the mental vessels and nerve. Running backwards and upwards from the mental tubercle is a faint ridge, the *oblique line*, which is continuous with the anterior border of the ramus; the Quadratus labii inferioris and Triangularis are attached to it, and the Platysma below it.

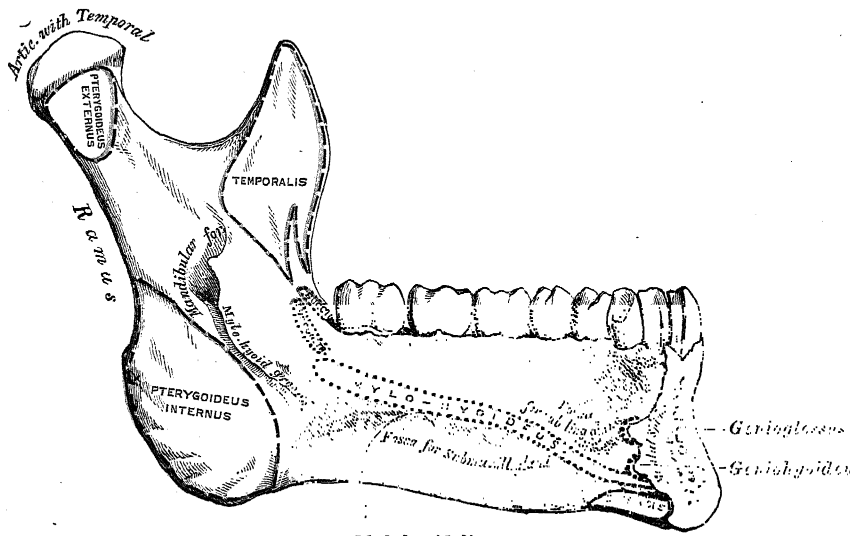
The *internal surface* (fig. 340) is concave from side to side. Near the lower part of the symphysis is a pair of laterally placed spines, termed the *mental spines*, which give origin to the Genioglossi. Immediately below these is a second pair of spines, or more frequently a median ridge or impression, for the origins of the Geniohyoidei. In some bones the mental spines are fused to form a single eminence; in others they are absent, and their position is indicated merely by an irregularity of the surface. Above the mental spines a median foramen and furrow are sometimes present; they mark the line of union of the halves of the bone. Below the mental spines, on either side of the middle line, is an oval depression, the *digastric fossa*, for the attachment of the anterior belly of the Digastricus. Extending upwards and backwards on either side from the lower part of the symphysis to a point behind the last molar tooth is the *mylohyoid line* which gives origin to the Mylohyoideus; the posterior part of this line, near the alveolar margin, gives attachment to a small part of the Constrictor pharyngis superior, and to the pterygomandibular raphe. Above the anterior part of this line is a smooth triangular area against which the sublingual gland rests, and below the posterior part, an oval fossa for a part of the submaxillary gland.

The *alveolar part* or upper portion of the body is hollowed into sixteen cavities or alveoli, for the reception of the roots of the teeth; these cavities vary in depth and size, and are single or subdivided by septa, according to the teeth which they contain. From the external surface of the alveolar part the Buccinator takes origin as far forwards as the first molar tooth. The

inferior border or *base* of the mandible is rounded, and is thicker in front than behind : at the point where it is continuous with the lower border of the ramus a shallow groove, for the external maxillary artery, may be present.

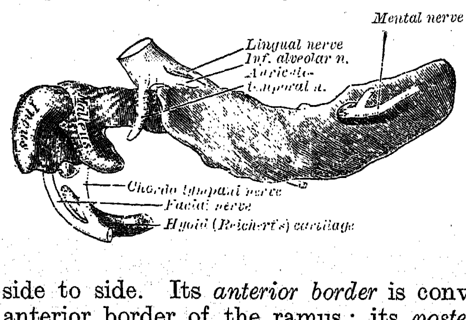
The **ramus** of the mandible is quadrilateral in shape, and has two surfaces, four borders, and two processes. The *lateral surface* (fig. 339) is flat and marked by oblique ridges at its lower part ; it gives attachment throughout nearly the whole of its extent to the Masseter. The *medial surface* (fig. 340) presents about its centre the *mandibular foramen*, which transmits the inferior

FIG. 340.—The left half of the mandible. Medial aspect.



alveolar vessels and nerve. The foramen is overlapped in front by a triangular process, the *lingula mandibulæ*, to the margins of which the sphenomandibular ligament is attached. Behind the lingula is a notch from which the *mylohyoid groove* runs obliquely downwards and forwards ; this groove lodges the mylohyoid vessels and nerve. Behind the groove is a rough surface for the insertion of the Pterygoideus internus. Into the anterosuperior part of the medial surface a portion of the Temporalis is inserted. The *lower border* of the ramus is thick, straight, and continuous with the inferior border of the body of the bone. At its junction with the posterior border is the *angle* of the mandible, which may be either inverted or everted, and is marked by rough, oblique ridges on either surface, for the insertion of the Masseter laterally, and the Pterygoideus internus medially ; the stylomandibular ligament is attached to the angle, between these muscles. The *anterior border*, thin above and thick below, is continuous with the oblique line. The *posterior border*, thick, smooth and rounded, is covered by the parotid gland. The *upper border* is surmounted by two processes, the *coronoid* in front and the *condyloid* behind ; these are separated by a deep concavity, the *mandibular notch*, which transmits the masseteric nerve and vessels.

FIG. 341.—The right half of the mandible of a human embryo 24 mm. long. Lateral aspect. (From a model by Low.)

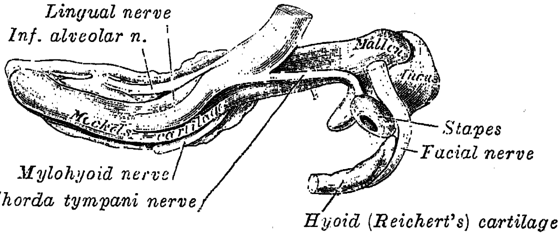


The *coronoid process* of the mandible is a thin, triangular eminence, which is flattened from side to side. Its *anterior border* is convex and is continuous below with the anterior border of the ramus ; its *posterior border* is concave and forms the anterior boundary of the mandibular notch. Its *lateral surface* is smooth, and

affords insertion to the Masseter and Temporalis. Its *medial surface* gives insertion to the Temporalis, and presents a ridge which begins near the apex of the process and runs downwards and forwards to the medial side of the last molar tooth. Between this ridge and the anterior border is a grooved triangular area, the upper part of which gives attachment to the Temporalis, the lower part to some fibres of the Buccinator.

The *condyloid process* of the mandible is thicker than the coronoid process, and consists of two portions; the condyle, and the constricted neck which supports it. The *condyle* articulates with the articular disc of the temporomandibular joint; it is convex from before backwards and from side to side, and its articular surface extends lower on the posterior than on the anterior surface. The long axis of the condyle is directed medialwards and slightly backwards, and if prolonged to the middle line will meet that of the opposite condyle near the anterior margin of the foramen magnum. At the lateral extremity of the condyle is a small tubercle for the attachment of the mandibular ligament. The *neck* is flattened from before backwards, and strengthened by ridges which descend from the sides and the lateral part of the front of the condyle. Its posterior surface is convex; on its anterior surface is a depression, the *pterygoid fovea*, for the attachment of the Pterygoideus externus.

FIG. 342.—The right half of the mandible of a human embryo 24 mm. long. Medial aspect. (From a model by Low.)



The *mandibular canal* runs from the mandibular foramen obliquely downwards and forwards in the ramus, and then horizontally forwards in the body beneath the alveoli, with which it communicates by small openings. It contains the inferior alveolar vessels and nerve, from which branches enter the roots of the teeth. Between the roots of the first and second premolar teeth the mandibular canal divides into the *mental* and *incisive canals*; the mental canal runs upwards, backwards and lateralwards and ends at the mental foramen; the incisive canal is continued forward below the incisor teeth.

Ossification.—The mandible is ossified in the fibrous membrane covering the outer surfaces of Meckel's cartilages. These two cartilages, a right and a left, form the cartilaginous bar of the mandibular arch (p. 76). Their dorsal or cranial ends are connected with the cartilaginous ear-capsules, and their ventral ends are joined to one another by mesodermal tissue. They run forwards immediately below the mandibular condyles and then, bending downwards, lie in a groove near the lower border of the bone; in front of the canine teeth they incline upwards to the symphysis. From the proximal end of each cartilage the malleus and incus, two of the three ossicles of the middle ear, are developed; the next succeeding portion, as far as the lingula of the mandible, is replaced by fibrous tissue which forms the sphenomandibular ligament. Between the lingula and the canine tooth the cartilage disappears, whilst the portion of it below and behind the incisor teeth is ossified and incorporated with this part of the mandible.

Ossification takes place in the membrane covering the outer surfaces of Meckel's cartilages (figs. 341 to 344), and each half of the bone is formed from one centre * which appears, near the mental foramen, about the sixth week of fœtal life. By the tenth week the portion of Meckel's cartilage which lies below and behind the incisor teeth is surrounded and invaded by the membrane-bone. Somewhat later, accessory pieces of cartilage make their appearance—viz. a wedge-shaped piece in the condyloid process and extending downwards through the ramus; a small patch along the anterior border of the coronoid process; and smaller nodules in the front part of both alveolar walls and along the front of the lower border of the bone.

* A. Low, *Proceedings of the Anatomical and Anthropological Society of the University of Aberdeen*, 1905, and *Journal of Anatomy and Physiology*, vol. xliv., and E. Fawcett, *Journal of the American Medical Association*, September 2, 1905.

These accessory nodules of cartilage possess no separate ossific centres, but are invaded by the surrounding membrane-bone and undergo absorption. The inner alveolar border, formerly described as arising from a separate *splenial* centre, is

FIG. 343.—The right half of the mandible of a human embryo 95 mm. long. Lateral aspect. (The nuclei of cartilage are stippled.) (From a model by Low.)

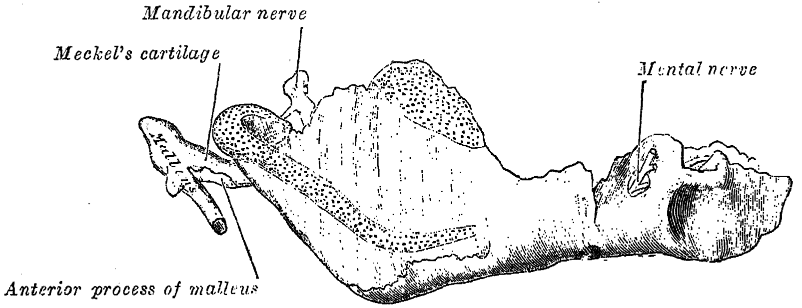
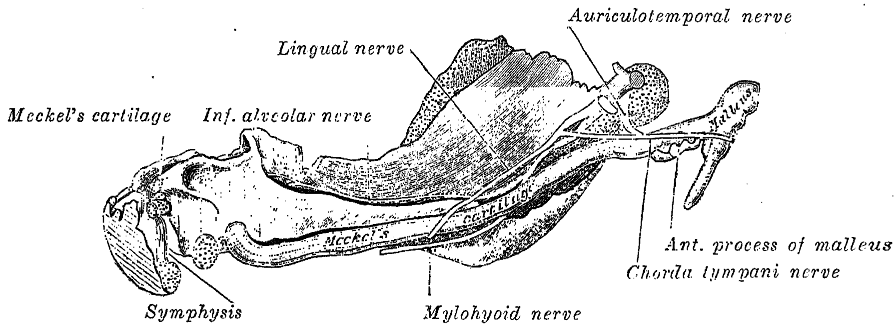


FIG. 344.—The right half of the mandible of a human embryo 95 mm. long. Medial aspect. (The nuclei of cartilage are stippled.) (From a model by Low.)



formed in the human mandible by an ingrowth from the main mass of the bone. At birth the bone consists of two parts, united by a fibrous symphysis, in which ossification takes place during the first year.

THE CHANGES PRODUCED IN THE MANDIBLE BY AGE

At birth (fig. 345) the body of the bone is a mere shell, containing on either side the sockets of the deciduous teeth, imperfectly partitioned off from one another. The mandibular canal runs near the lower border of the bone, and the mental foramen opens beneath the socket of the first deciduous molar tooth. The angle is obtuse (175°), and the condyloid portion is nearly in line with the body. The coronoid process is relatively large, and projects above the level of the condyle.

After birth (fig. 346) the two segments of the bone become joined at the symphysis from below upwards, in the first year; but a trace of separation may be visible in the beginning of the second year, near the alveolar margin. The body elongates, but more especially behind the mental foramen to provide space for the three additional teeth developed in this part. The depth of the body increases by growth of the alveolar part of the bone, to afford room for the roots of the teeth, and by thickening of the sub-alveolar portion. After the second dentition, the mandibular canal is situated just above the level of the mylohyoid line, and the mental foramen occupies the position usual to it in the adult. By the fourth year the angle is reduced to about 140°.

In the adult (fig. 347) the alveolar and subalveolar portions of the body are of about equal depth. The mental foramen opens midway between the upper and lower borders of the bone, and the mandibular canal runs nearly parallel with the mylohyoid line. The ramus is almost vertical in direction, the angle measuring from 110° to 120°.

In old age (fig. 348) the bone is reduced in size, for with the loss of the teeth the alveolar process is absorbed, and, consequently, the mandibular canal and the mental foramen are close to the alveolar border. The ramus is oblique in direction, the angle measures about 140°, and the neck of the condyle is more or less bent backwards.

THE MANDIBLE AT DIFFERENT PERIODS OF LIFE. LEFT LATERAL ASPECT.

FIG. 345.—At birth.

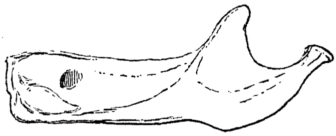


FIG. 346.—In childhood.

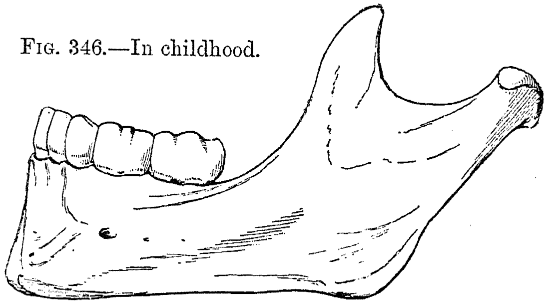


FIG. 347.—In the adult.

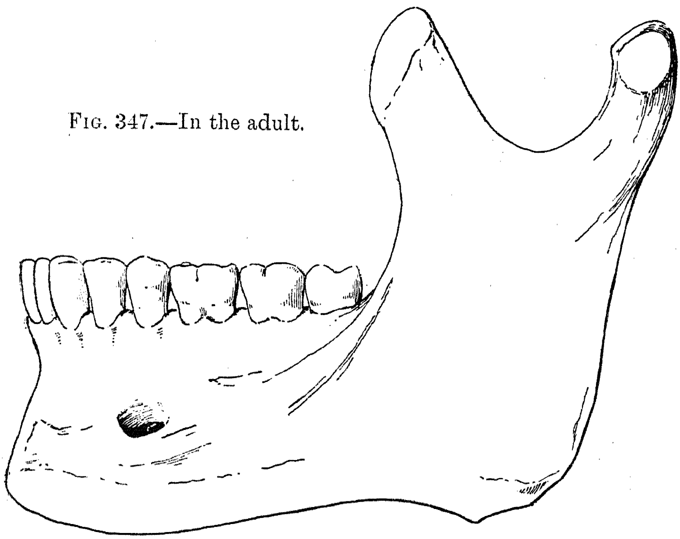
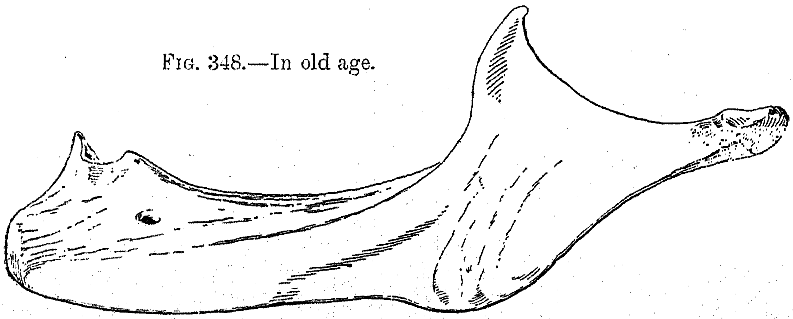


FIG. 348.—In old age.



THE HYOID BONE (OS HYOIDEUM)

The **hyoid bone** (fig. 349) is U-shaped, and is suspended from the tips of the styloid processes of the temporal bones by the stylohyoid ligaments. It consists of a body, two greater and two lesser cornua.

The **body** or central part of the hyoid bone is of a quadrilateral form. Its *anterior surface* is convex and directed forwards and upwards. Its upper part is crossed by a well-marked ridge which has a slight downward convexity, and in many cases a vertical median ridge divides the body into lateral halves. The portion of the vertical ridge above the transverse line is present in a majority of specimens, but that below the transverse line is rarely seen. The anterior surface gives insertion to the Geniohyoideus in the greater part of its extent both above and below the transverse ridge ; a portion of the origin of the Hyoglossus notches the lateral margin of the Geniohyoideus attachment. Below the transverse ridge the Mylohyoideus, Sternohyoideus, and Omohyoideus are inserted. The *posterior surface* is smooth, concave, directed backwards

FIG. 349.—The hyoid bone. Antero-superior aspect.

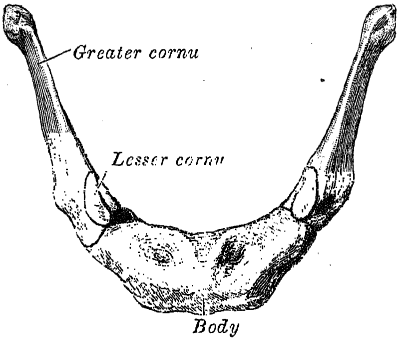
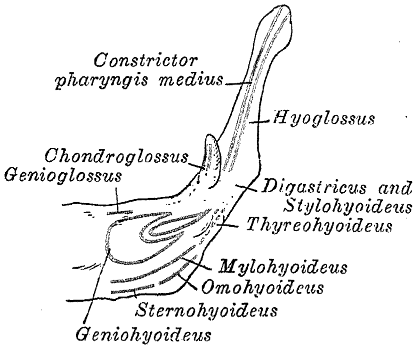


FIG. 350.—A sketch of left half of the hyoid bone to show the muscular attachments.



and downwards, and separated from the epiglottis by the hyothyreoid membrane and a quantity of loose areolar tissue ; a bursa intervenes between the bone and the membrane. The *superior border* is rounded, and gives attachment to the hyothyreoid membrane and to some aponeurotic fibres of the Genioglossus. The *inferior border* affords insertion medially to the Sternohyoideus and laterally to the Omohyoideus and occasionally a portion of the Thyreohyoideus. It also gives attachment to the Levator glandulæ thyreoideæ, when this muscle is present. In early life the *lateral borders* of the body are connected to the greater cornua by synchondroses, but after middle life they are usually united by bone.

The **greater cornua** of the hyoid bone project backwards from the lateral borders of the body ; they are flattened from above downwards and diminish in size from before backwards. Each cornua ends posteriorly in a tubercle to which the lateral hyothyreoid ligament is fixed. The *upper surface* is rough close to its lateral border, for muscular attachments : the largest of these are the origins of the Hyoglossus and Constrictor pharyngis medius which extend along the whole length of the cornu ; the Digastricus and Stylohyoideus have small insertions in front of these, near the junction of the body with the cornu. To the *medial border* the hyothyreoid membrane is attached, while the anterior half of the *lateral border* gives insertion to the Thyreohyoideus.

The **lesser cornua** of the hyoid bone are two small, conical eminences, attached by their bases at the angles of junction of the body and greater cornua. They are connected to the body of the bone by fibrous tissue and occasionally to the greater cornua by diarthrodial joints, which usually persist throughout life, but occasionally become ankylosed.

The lesser cornua are situated in the line of the transverse ridge on the body

and appear to be morphological continuations of it.* The apex of each cornu gives attachment to the stylohyoid ligament †; the Chondroglossus rises from the medial side of the base.

Ossification.—The hyoid bone is developed from the cartilages of the second and third branchial or visceral arches—the lesser cornua from the second, the greater cornua from the third, and the body from the fused ventral ends of both arches (p. 77). It is ossified from six centres: two for the body, and one for each cornu. Ossification commences in the greater cornua towards the end of fœtal life, in the body before or shortly after birth, and in the lesser cornua during the first or second year, or later.

THE EXTERIOR OF THE SKULL

The skull as a whole may be viewed from above (norma verticalis), from below (norma basalis), from the side (norma lateralis), from behind (norma occipitalis), or from the front (norma frontalis).

Norma Verticalis

When viewed from above, the outline of the skull varies greatly in different specimens; in some it is more or less oval, in others more nearly circular. The surface is traversed by three sutures, viz.: (1) the coronal, nearly transverse in direction, between the frontal and parietal bones; (2) the sagittal, in the median plane, between the parietal bones, and deeply serrated in its anterior two-thirds; and (3) the upper part of the lambdoid, between the occipital and parietal bones. The point of junction of the sagittal and coronal sutures is named the bregma, that of the sagittal and lambdoid sutures, the lambda; they indicate respectively the positions of the anterior and posterior fonticuli of the fœtal skull. On either side of the sagittal suture are the parietal tuberosity or eminence and the parietal foramen—the latter, however, is frequently absent on one or both sides. The skull is often somewhat flattened in the neighbourhood of the parietal foramina, and the term obelion is applied to that point of the sagittal suture which is on a level with the foramina. At the front of the skull are the frontal tuberosities or eminences; below these are the superciliary arches, joined to one another by the elevation of the glabella. Immediately above the glabella the remains of the frontal suture may be seen; in infancy this suture divides the frontal bone into two parts, a condition which persists in about 9 per cent. of skulls. Passing backwards and upwards from the zygomatic processes of the frontal bone are the temporal lines, which mark the upper limits of the temporal fossæ. The zygomatic arches may or may not be seen projecting beyond the anterior portions of these lines.

Norma Basalis (Basis Cranii Externa) (figs. 351, 352)

The external surface of the base of the skull, exclusive of the mandible, is bounded in front by the incisor teeth in the maxillæ; behind, by the superior nuchal lines of the occipital bone; and laterally by the alveolar arch, the lower border of the zygomatic bone, the zygomatic arch and an imaginary line drawn from this arch to the mastoid process of the temporal bone and the superior nuchal line of the occipital bone. The anterior part or hard palate projects below the level of the rest of the surface, and is bounded in front and laterally by the alveolar arch containing the sixteen teeth of the maxillæ (fig. 329). Immediately behind the incisor teeth is the incisive foramen. In this foramen are two lateral apertures, the openings of the incisive canals (foramina of Stensen); each of these leads upwards into the corresponding nasal cavity and transmits

* F. G. Parsons, *Journal of Anatomy and Physiology*, vol. xliii.

† These ligaments may undergo partial ossification.

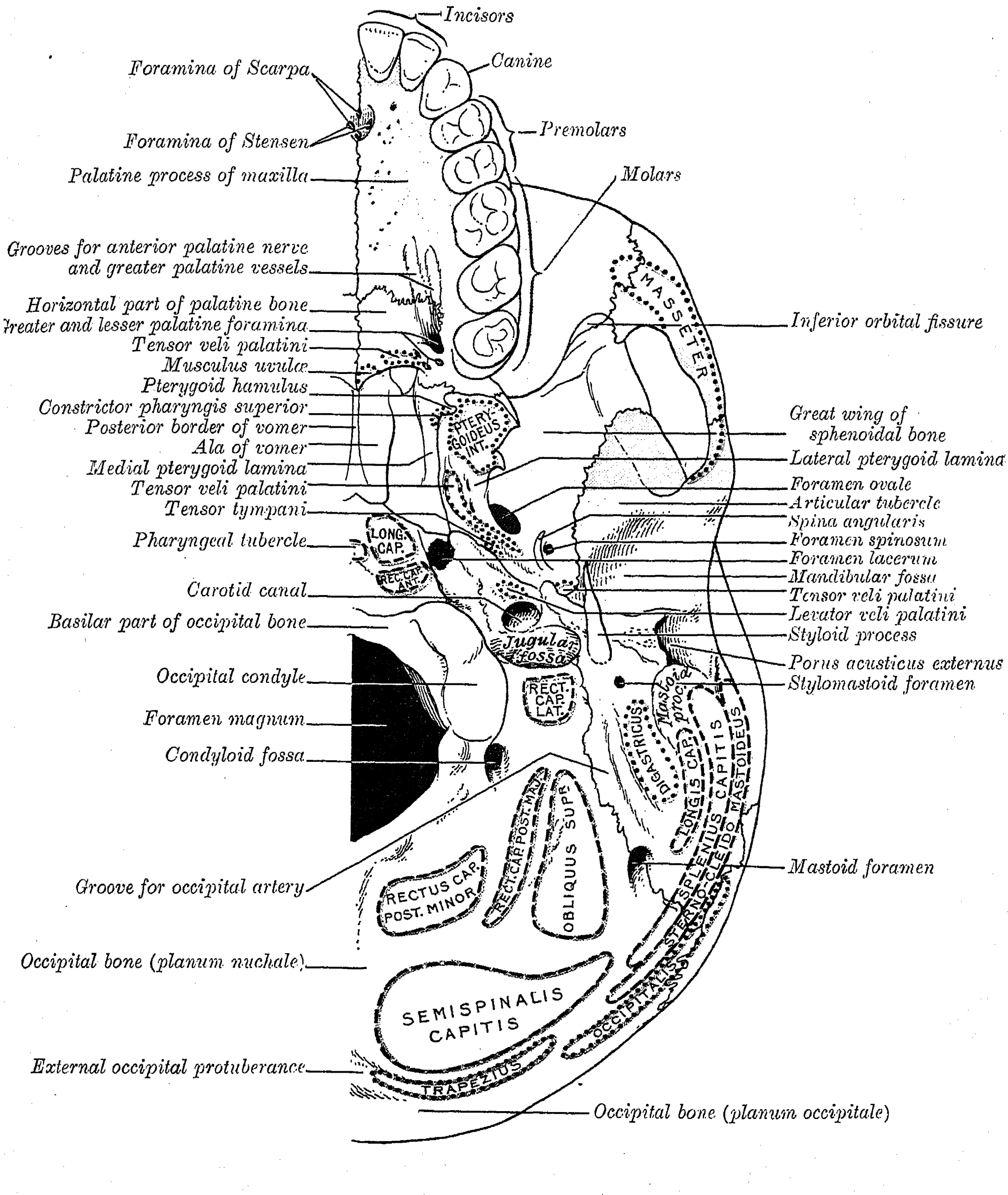
the terminal branches of the greater palatine vessels and the nasopalatine nerve. Occasionally there are two additional apertures (foramina of Scarpa) in the middle line; when these foramina are present the nasopalatine nerves pass through them instead of through the foramina of Stensen, the left nerve

FIG. 351.—The external surface of the left half of the base of the skull. (Norma basalis.)

being usually transmitted through the anterior, and the right through the posterior foramen. The vault of the hard palate is concave, uneven, perforated by numerous foramina, and marked by depressions for the palatine glands; its posterior part is traversed by a cruciate suture formed by the junction of the four bones of which it is composed. In the young skull a suture may be present, extending on either side from the incisive foramen to the interval between the lateral incisor and canine teeth, and marking off in front of it the os incisivum or premaxillary bone. At either posterior angle of the hard palate is the

greater palatine foramen, for the transmission of the greater palatine vessels and the anterior palatine nerve; and running forwards and medialwards from the foramen are two grooves, for the same vessels and nerve. Behind the greater palatine foramen is the pyramidal process of the palatine bone, per-

FIG. 352.—Key to fig. 351.



forated by two or three lesser palatine foramina, and marked by a curved ridge which is continued on the horizontal part of the bone, and gives attachment to part of the aponeurosis of the Tensor veli palatini. Projecting backwards from the middle of the posterior border of the hard palate is the posterior nasal spine, from which the Musculus uvulæ takes origin.

Behind and above the hard palate are the choanæ, each measuring about 2·5 cm. vertically and 1·25 cm. transversely. They are separated from one another by the vomer and each is bounded above by the body of the sphenoidal

bone and the vaginal process of the medial pterygoid lamina, below by the horizontal part of the palatine bone, and laterally by the medial pterygoid lamina. At the superior border of the vomer are the expanded alæ of this bone, which receive between them the rostrum of the sphenoidal bone, and articulate laterally with the sphenoidal processes of the palatine bones and the vaginal processes of the medial pterygoid laminæ. Below the vaginal processes are the pharyngeal canals. The medial pterygoid lamina is long and narrow; lateral to its upper part is the scaphoid fossa, for the origin of the Tensor veli palatini; this muscle descends in contact with the medial surface of the lamina, and its tendon turns round the hamulus at the lower end of the lamina. At the upper end of the medial pterygoid lamina is the pterygoid tubercle, and immediately above this tubercle, the posterior end of the pterygoid canal. The lateral pterygoid lamina is broad; its lateral surface forms the medial boundary of the infratemporal fossa, and gives origin to the lower head of the Pterygoideus externus. Its medial surface forms the lateral wall of the pterygoid fossa, and gives origin to the greater part of the Pterygoideus internus.

Behind the choanæ are the posterior part of the body of the sphenoidal bone and the basilar portion of the occipital bone; near the centre of the latter is the pharyngeal tubercle for the attachment of the fibrous raphe of the pharynx, and on either side of the middle line are depressions for the insertions of the Longus capitis and Rectus capitis anterior. Behind the upper end of the lateral pterygoid lamina is the foramen ovale, for the transmission of the mandibular nerve, the accessory meningeal artery, and sometimes the lesser superficial petrosal nerve; behind the foramen ovale are the foramen spinosum and the spina angularis of the sphenoidal bone; the former transmits the middle meningeal artery and the nervus spinosus, the latter gives attachment to the sphenomandibular ligament and to a part of the Tensor veli palatini. Lateral to the spina angularis is the mandibular fossa, divided into two parts by the petrotympanic fissure; the anterior portion of the fossa, concave, smooth and bounded in front by the articular tubercle, articulates with the articular disc of the mandibular joint; the posterior portion, bounded behind by the tympanic part of the temporal bone, is sometimes occupied by a part of the parotid gland. Emerging from the vagina processus styloidei of the tympanic part of the temporal bone is the styloid process; and behind the upper end of this process is the stylomastoid foramen, for the exit of the facial nerve, and entrance of the stylomastoid artery. Lateral to the stylomastoid foramen, between the tympanic part and the mastoid process, is the tympanomastoid fissure, which gives exit to the auricular branch of the vagus nerve. Medial to the mastoid process is the mastoid notch (digastric fossa) for the posterior belly of the Digastricus, and medial to the mastoid notch, the groove for the occipital artery. At the base of the medial pterygoid lamina is the foramen lacerum, bounded anteriorly by the great wing of the sphenoidal bone, posteriorly and laterally by the apex of the petrous portion of the temporal bone, and medially by the body of the sphenoidal bone and the basilar portion of the occipital bone; it presents in front, the posterior orifice of the pterygoid canal; behind, the superior aperture of the carotid canal. In the recent state the lower part of the foramen lacerum is filled up by a fibrocartilaginous plate, on the upper surface of which the internal carotid artery rests. Between the petrous part of the temporal bone and the great wing of the sphenoidal bone is the sulcus tubæ auditivæ. This sulcus, directed lateralwards and backwards, lodges and gives attachment to the cartilaginous part of the auditory tube, and is continuous behind with the semicanalis tubæ auditivæ in the temporal bone. In the floor of this sulcus is the petrosphenoidal fissure, occupied, in the recent condition, by a plate of cartilage. Behind this fissure is the under surface of the petrous portion of the temporal bone, presenting, near its apex, a quadrilateral rough surface, part of which gives origin to the Levator veli palatini; lateral and posterior to this surface is the inferior orifice of the carotid canal, and medial to this orifice, the depression leading to the aquæductus cochleæ. Behind the inferior orifice of the carotid canal is the jugular foramen, formed in front and laterally by the petrous portion of the temporal bone, behind and medially by the occipital bone; it is generally larger on the right than on the left side of the skull. The anterior part of the jugular foramen transmits the inferior petrosal sinus; the intermediate, the glossopharyngeal,

vagus, and accessory nerves; the posterior, the transverse sinus and some meningeal branches from the occipital and ascending pharyngeal arteries. On the ridge of bone between the inferior orifice of the carotid canal and the jugular foramen is the inferior tympanic canaliculus for the passage of the tympanic branch of the glossopharyngeal nerve, and in the lateral part of the jugular foramen, near the root of the styloid process, is the mastoid canaliculus for the passage of the auricular branch of the vagus nerve. Running from the jugular foramen to the foramen lacerum is the petro-occipital fissure, occupied, in the recent state, by a plate of cartilage. Behind the basilar portion of the occipital bone is the foramen magnum which transmits the medulla oblongata and its membranes, the spinal parts of the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, and the ligaments connecting the occipital bone with the epistropheus or axis vertebra. Lateral to the anterior half of the foramen magnum are the occipital condyles for articulation with the atlas vertebra; the medial side of each condyle is rough for the attachment of the alar ligament. Lateral to the condyle is the jugular process of the occipital bone, which gives attachment to the Rectus capitis lateralis. In front of the condyle is the hypoglossal canal for the passage of the hypoglossal nerve and a meningeal artery. Behind the condyle is the condyloid fossa, which is sometimes perforated by the condyloid canal for the transmission of a vein from the transverse sinus. Behind the foramen magnum is the median nuchal line, ending above at the external occipital protuberance; on either side are the superior and inferior nuchal lines, which, with the surfaces of bone between them, are rough for the attachment of the muscles enumerated on p. 196.

Norma Lateralis (fig. 353)

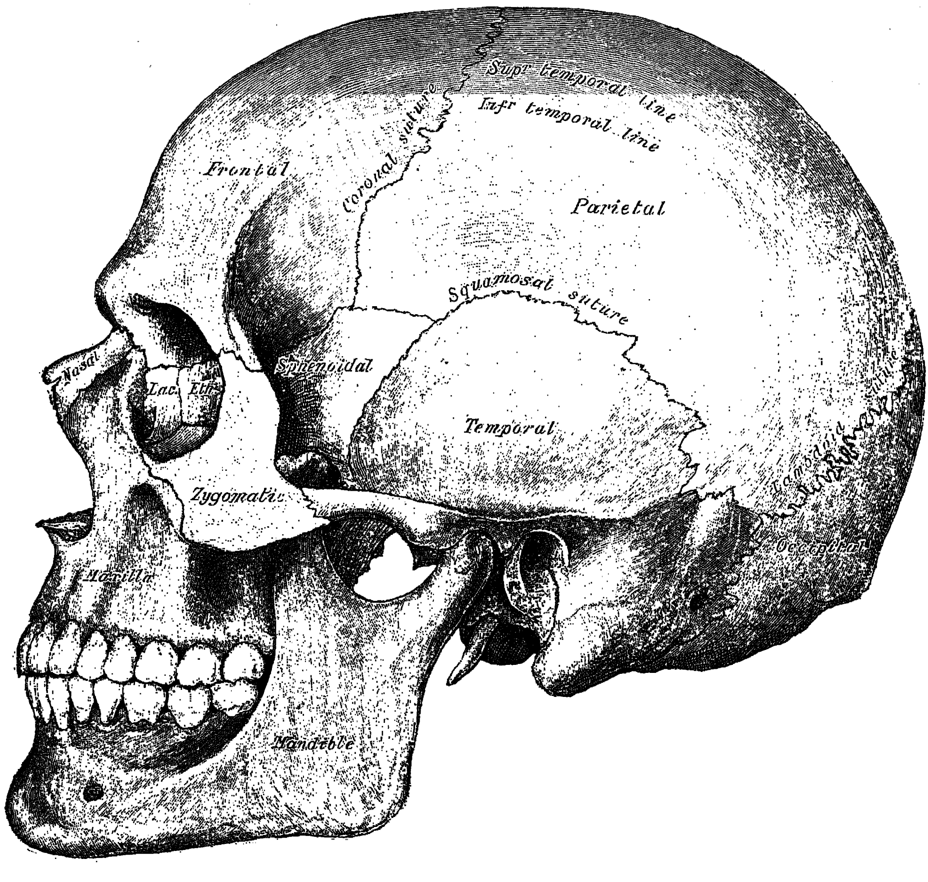
When viewed from the side the skull is seen to consist of the cranium above and behind, and the face below and in front. The cranium is somewhat ovoid in shape, but its contour varies in different cases, and depends largely on the length and height of the skull and on the degree of prominence of the superciliary arches and frontal tuberosities. Entering into its formation are the frontal, parietal, occipital, temporal, and sphenoidal bones. These bones are joined to one another by the coronal, sphenofrontal, sphenoparietal, sphenosquamosal, squamosal, parietomastoid and lambdoid sutures. The sphenoparietal suture varies in length in different skulls, and is absent in those cases where the frontal bone articulates with the temporal squama; the posterior end of the sphenoparietal suture is named the pterion. The squamosal suture arches backwards from the pterion and connects the temporal squama with the lower border of the parietal bone; it is continuous behind with the short, nearly horizontal parietomastoid suture which unites the mastoid process of the temporal bone with the mastoid angle of the parietal bone. Extending across the cranium are the coronal and lambdoid sutures; the former connects the frontal and parietal bones; the latter, the occipital and parietal bones. The lambdoid suture is continuous below with the occipitomastoid suture between the occipital bone and the mastoid portion of the temporal bone; in or near the latter suture is the mastoid foramen which transmits an emissary vein.

Immediately above the orbital margin is the superciliary arch, and, at a higher level, the frontal tuberosity. Near the centre of the parietal bone is the parietal tuberosity. Posteriorly is the external occipital protuberance, from which the superior nuchal line may be followed to the mastoid process. The temporal lines arch across the side of the cranium and mark the upper limit of the temporal fossa.

The *temporal fossa* is bounded above and behind by the temporal lines, which extend from the zygomatic process of the frontal bone upwards and backwards across the frontal and parietal bones, and then curve downwards and forwards to the temporal bone to become continuous with the supramastoid crest and the posterior root of the zygomatic arch. The temporal fossa is bounded in front by the frontal and zygomatic bones; opening on the latter is the zygomaticotemporal foramen. Laterally the fossa is limited by the zygomatic arch; below, it is separated from the infratemporal fossa by the infratemporal crest on the great wing of the sphenoidal bone, and by a

ridge which runs backwards from this crest across the temporal squama to the anterior root of the zygomatic process. The floor of the fossa, deeply concave in front, is formed by the zygomatic, frontal, parietal, sphenoidal, and temporal bones. It is traversed by vascular furrows: one, usually well marked, runs upwards above the opening of the external acoustic meatus, and lodges the middle temporal artery. Two others, frequently indistinct, may be observed on the anterior part of the floor, and are for the anterior and posterior deep temporal arteries. The temporal fossa contains the Temporalis muscle and its vessels and nerves, together with the zygomaticotemporal nerve.

FIG. 353.—The skull. Lateral aspect. (Norma lateralis.)



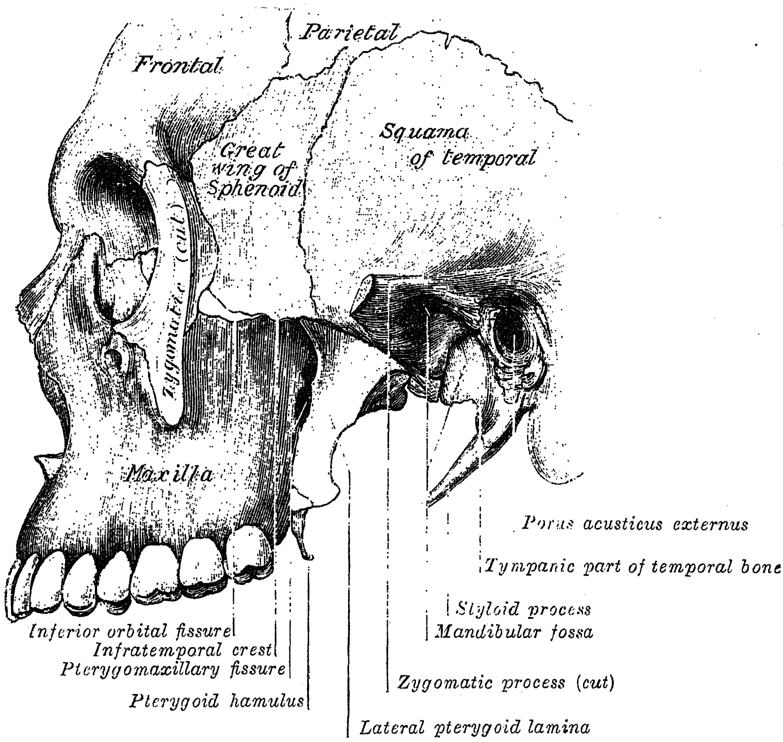
The *zygomatic arch* is formed by the union of the zygomatic process of the temporal bone with the temporal process of the zygomatic bone; the tendon of the Temporalis descends on the medial side of the arch to gain insertion into the coronoid process of the mandible. The zygomatic process of the temporal bone arises by two roots, an anterior, directed inwards in front of the mandibular fossa, where it expands to form the articular tubercle, and a posterior which runs backwards above the opening of the external acoustic meatus and is continuous with the temporal line. The upper border of the zygomatic arch gives attachment to the temporal fascia; the lower border and medial surface of the arch give origin to the Masseter.

Below the posterior root of the zygomatic arch is the porus acusticus externus, to the circumference of which the cartilaginous segment of the external acoustic meatus is attached. The small triangular area between the supramastoid crest and the posterosuperior part of the porus acusticus externus is termed the suprameatal triangle, and on the anterior border of this triangle, the suprameatal spine is sometimes seen. Between the tympanic

part and the articular tubercle is the mandibular fossa; behind the fossa the styloid process extends downwards and forwards for a variable distance; it gives attachment to the Styloglossus, Stylohyoideus, and Stylopharyngeus muscles, and to the stylohyoid and stylomandibular ligaments. Projecting downwards behind the porus acusticus externus is the mastoid process, to the outer surface of which the Sternocleidomastoideus, Splenius capitis, and Longissimus capitis are attached.

The *infratemporal fossa* (fig. 351) is an irregularly shaped space, situated medial to the zygomatic arch and the coronoid process of the mandible. It is bounded in front by the infratemporal surface of the maxilla, and by a ridge which ascends from the socket of the first molar tooth; behind, by the articular tubercle of the temporal bone and the spina angularis of the sphenoidal

Fig. 354.—The left infratemporal fossa.



bone; above, by the great wing of the sphenoidal bone below the infratemporal crest, and a small triangular part of the temporal squama in front of the articular tubercle; below, by the alveolar border of the maxilla; medially, by the lateral pterygoid lamina. It contains the lower part of the Temporalis, the Pterygoidei internus et externus, the internal maxillary vessels, and the mandibular and maxillary nerves. The foramen ovale and foramen spinosum open on its roof, and the alveolar canals, on its anterior wall. At the upper and medial part of the fossa are two fissures, which meet at a right angle, the horizontal limb being the inferior orbital fissure, and the vertical limb the pterygomaxillary fissure.

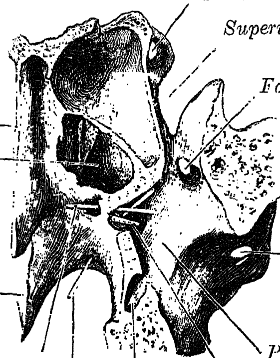
The *inferior orbital fissure* (sphenomaxillary fissure), nearly horizontal in direction, opens into the lateral and posterior part of the orbit. It is bounded above by the lower border of the orbital surface of the great wing of the sphenoidal bone; below, by the lateral border of the orbital surface of the maxilla and the orbital process of the palatine bone; laterally, by a small part of the zygomatic bone *; medially, it joins at right angles with the pterygo-

* In from 35 to 40 per cent. of skulls the maxilla and the sphenoidal bone articulate with each other at the lateral end of this fissure, and exclude the zygomatic bone from it.

maxillary fissure. Through the inferior orbital fissure the orbit communicates with the infratemporal and pterygopalatine fossæ; the fissure transmits the maxillary nerve and its zygomatic (temporomalar) branch, the infra-orbital vessels, the orbital branches of the sphenopalatine ganglion, and veins which connect the inferior ophthalmic vein with the pterygoid venous plexus.

The *pterygomaxillary fissure* is vertical, and descends at right angles from the medial end of the inferior orbital fissure; it is a triangular interval, formed by the divergence of the maxilla from the pterygoid process of the sphenoidal bone. It connects the infratemporal fossa with the pterygopalatine fossa, and transmits the terminal part of the internal maxillary artery.

FIG. 355.—A section showing the posterior wall of the pterygopalatine fossa.



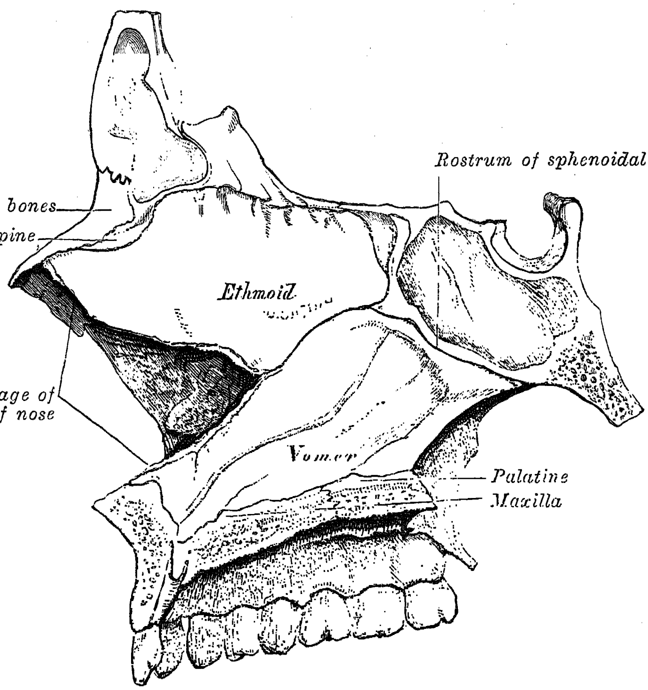
The *pterygopalatine fossa* (sphenomaxillary fossa) (figs. 355, 360) is a small, pyramidal space situated beneath the apex of the orbit at the angle of junction of the inferior orbital and pterygomaxillary fissures. It is bounded above by the under surface of the body of the sphenoidal bone and by the orbital process of the palatine bone; in front, by the upper part of the infratemporal surface of the maxilla; behind, by the base of the pterygoid process and the lower part of the anterior surface of the great wing of the sphenoidal bone; medially, by the vertical part of the palatine bone with its orbital and sphenoidal processes. The fossa contains the maxillary nerve, the sphenopalatine ganglion, and the terminal part of the internal maxillary artery. Five foramina open into it. Of these, three are on the posterior wall, viz.: the foramen rotundum, the pterygoid canal, and the pharyngeal canal, in this order downwards and medialwards; on the medial wall is the sphenopalatine foramen; below is the superior orifice of the pterygopalatine canal.

NORMA OCCIPITALIS

When viewed from behind, the cranium presents a more or less circular outline. In the upper portion of the middle line is the posterior part of the sagittal suture connecting the parietal bones; extending downwards and lateralwards from the posterior end of this suture is the deeply serrated lambdoid suture joining the occipital and parietal bones, and continuous below with the parietomastoid and occipitomastoid sutures; the lambdoid suture frequently contains one or more sutural bones (fig. 325). Near the middle of the occipital squama is the external occipital protuberance or inion, and, extending lateralwards from it, the superior nuchal lines, and above these the faintly marked highest nuchal lines. The surface of the occipital bone above the inion and highest nuchal lines is named the planum occipitale, and is covered by the Occipitalis muscle; the surface below is termed the planum nuchale, and is

its upper half articulates with the lamina perpendicularis of the ethmoidal bone, its lower is cleft for the reception of the inferior margin of the cartilage of the septum of the nose. The *posterior border* is free, concave, and separates the

FIG. 322.—The median wall of the left nasal cavity, showing the vomer *in situ.*



choanæ or posterior nasal apertures ; it is thick and bifid above, thin below. The anterior end of the vomer articulates with the posterior margin of the incisor crest of the maxillæ and projects downwards between the incisive canals.

Ossification.—At an early period the septum of the nose consists of a plate of cartilage. The superior part of this cartilage is ossified to form the lamina perpendicularis of the ethmoid ; its antero-inferior portion persists as the cartilage of the septum, whilst the vomer is ossified in the membrane covering its postero-inferior part. About the eighth week of fœtal life two centres of ossification, one on

FIG. 323.—The vomer. Left lateral aspect.

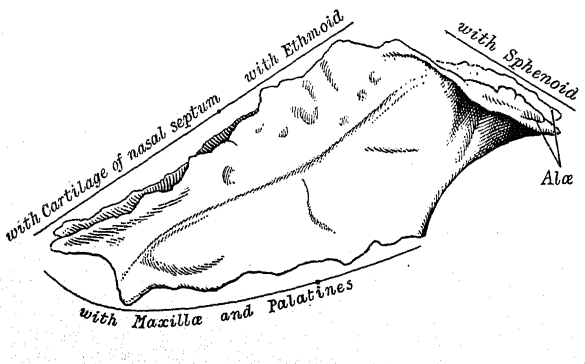
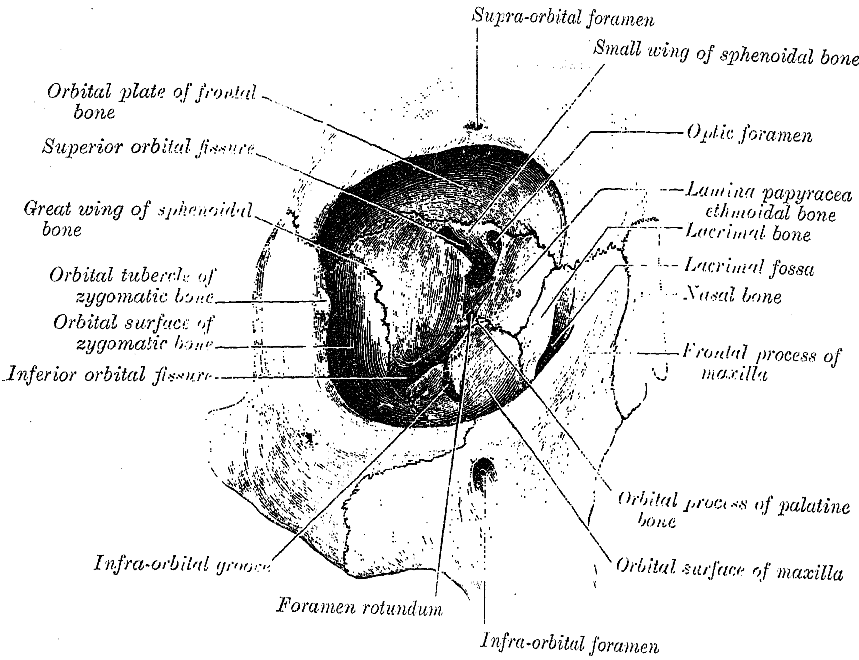


FIG. 324.—The vomer of an infant.

either side of the middle line, appear in this part of the membrane, medial to and a little behind the paraseptal cartilages (p. 76). About the third month these centres unite below the cartilage, and thus a deep groove is formed (fig. 324) in which the

joined to one another by the glabella. On and above the glabella a trace of the frontal suture sometimes persists; beneath the glabella is the frontonasal suture, below and behind which are the frontomaxillary and frontolacrimal sutures. Below each superciliary arch is the upper part of the circumference of the base of the orbit, thin and prominent in its lateral two-thirds, rounded in its medial one-third, and displaying at the junction of these two portions the supra-orbital notch or foramen for the supra-orbital nerve and vessels. The supra-orbital margin ends laterally in the zygomatic process, from which the temporal lines extend upwards and backwards. Below the frontonasal suture is the bridge of the nose, convex from side to side, concavo-convex from above downwards, and formed by the two nasal bones which are supported in the middle line by the nasal spine of the frontal bone and the lamina perpendicularis of the ethmoidal bone. The frontal processes of the maxillæ ascend between

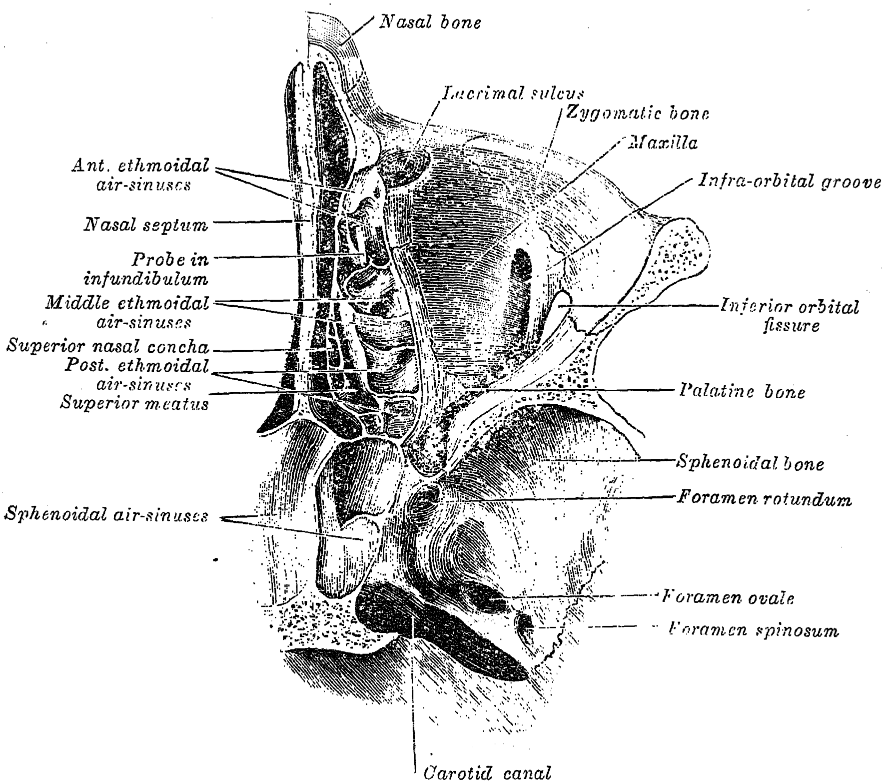
Fig. 357.—The right orbital cavity. Anterior aspect.



the nasal and lacrimal bones and form the lower and medial parts of the circumferences of the orbits. Below the nasal bones and between the maxillæ is the anterior aperture of the nasal cavity, pyriform in shape, with the narrow end directed upwards. Laterally this aperture is bounded by sharp margins which curve medialwards and forwards below, and end in the anterior nasal spine. On looking into the nasal cavity, the bony septum between the right and left nasal chambers presents, in front, a large triangular deficiency; this is filled in the recent state by the cartilage of the nasal septum; on the lateral wall of each nasal cavity the anterior part of the inferior nasal concha is visible. Below and lateral to the anterior nasal aperture are the anterior surfaces of the maxillæ, each perforated, near the lower margin of the orbit, by the infra-orbital foramen for the passage of the infra-orbital nerve and vessels. Below and medial to this foramen is the canine eminence separating the incisive from the canine fossa. Beneath these fossæ are the alveolar processes of the maxillæ containing the roots of the upper teeth; the front upper teeth overlap the corresponding lower teeth. The zygomatic bone on either side forms the prominence of the cheek and the anterior part of the zygomatic arch, and assists in forming the lower and lateral portion of the orbital cavity. It articulates medially with the maxilla, behind with the zygomatic process of the temporal bone, and the great wing of the sphenoidal bone, and above with the zygomatic process of the frontal bone; it is perforated by the zygomaticofacial foramen for the passage of the

zygomaticofacial nerve. On the upper part of the body of the mandible is a median ridge, indicating the position of the symphysis or junction of the two pieces of which the bone is composed at an early period of life; this ridge divides below to enclose the mental protuberance, the lateral angles of which are named the mental tubercles. Below the incisor teeth is the incisive fossa; beneath the second premolar tooth is the mental foramen which transmits the mental nerve and vessels. The oblique line ascends from the mental tubercle and is continuous behind with the anterior border of the ramus. The posterior border of the ramus runs downwards and forwards from the condyle to the angle which is more or less everted.

FIG. 358.—A horizontal section through the nasal and orbital cavities. Superior aspect.

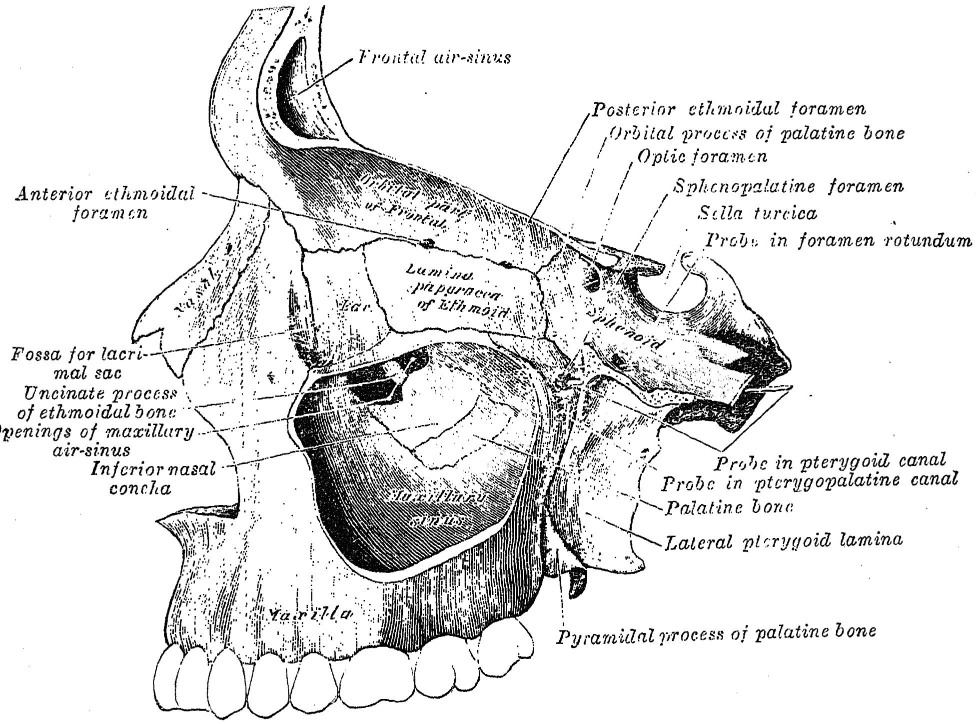


The **orbits** (figs. 356 to 360) are two pear-shaped cavities, situated at the junction of the cranium with the face, their bases being directed forwards and lateralwards, and their apices backwards and medialwards, so that the long axes of the cavities, if continued backwards, would meet over the body of the sphenoidal bone. Each orbit has a roof, a floor, a medial and a lateral wall, a base, and an apex.

The *roof* of the orbit is thin, triangular, and concave, and is directed downwards and slightly forwards. It separates the orbital from the cranial cavity, and its anteromedial part is double owing to the extension into it of the frontal air-sinus, and sometimes also the ethmoidal air-sinuses. It is formed in front by the orbital plate of the frontal bone, and behind by the small wing of the sphenoidal bone, which is pierced by the optic foramen. It presents, just within the base of the orbit and about midway between the supra-orbital notch and the frontolacrimal suture, a small depression or spine, the fovea vel spina trochlearis, for the attachment of the fibrocartilaginous pulley of the Obliquus oculi superior; on its anterolateral part is the lacrimal fossa for the lacrimal gland; posteriorly is the suture between the frontal bone and the small wing of the sphenoidal bone.

The *floor* of the orbit (fig. 358) looks upwards and lateralwards, and is the shortest of the four walls; it separates the orbital cavity from the maxillary air-sinus. Triangular in shape, it is formed chiefly by the orbital surface of the maxilla; in front and laterally, by the orbital process of the zygomatic bone; behind and medially, to a small extent, by the orbital process of the palatine bone. At its medial angle is the upper opening of the nasolacrimal canal, immediately to the lateral side of which is a small depression on the orbital surface of the maxilla for the origin of the Obliquus oculi inferior. On the lateral part of the floor is the suture between the maxilla and the zygomatic bone, and at its posterior part the suture between the maxilla and the orbital process of the palatine bone. Running forwards near the middle of the floor is the infra-orbital groove, ending anteriorly in the infra-orbital canal and transmitting the infra-orbital nerve and vessels.

Fig. 359.—The medial wall of the left orbit.

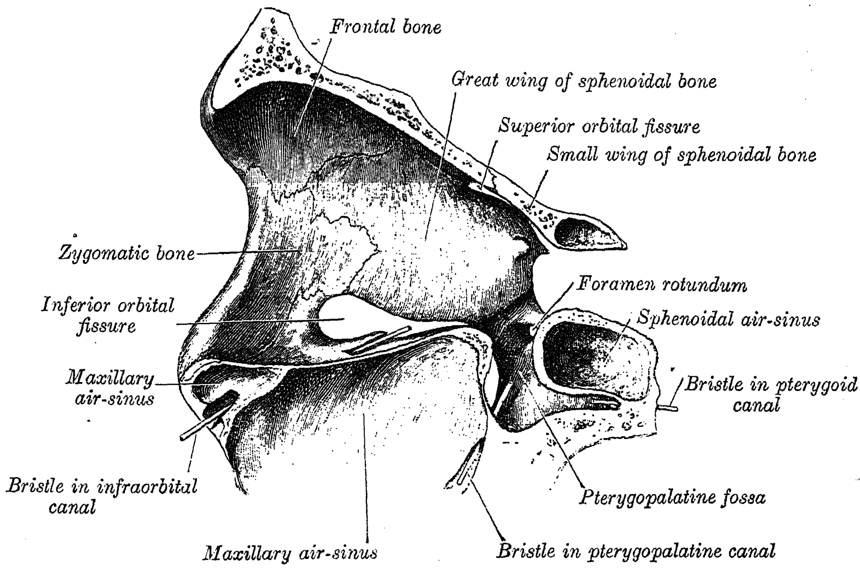


The *medial wall* of the orbit (fig. 359) is nearly vertical. It is very thin, and separates the orbital cavity from the ethmoidal air-sinuses, and from the anterior part of the sphenoidal air-sinus. It is formed from before backwards by the frontal process of the maxilla behind the anterior lacrimal crest, the lacrimal bone and the small part of the frontal bone directly above it, the lamina papyracea of the ethmoidal bone, and a small portion of the body of the sphenoidal bone in front of the optic foramen; sometimes the sphenoidal concha forms a small part of this wall (p. 205). It exhibits three vertical sutures, viz. the lacrimomaxillary, lacrimo-ethmoidal, and spheno-ethmoidal. In front is seen the lacrimal fossa, which lodges the lacrimal sac, and behind the fossa is the posterior lacrimal crest, from which the lacrimal part of the Orbicularis oculi arises. At the junction of the medial wall and the roof are the fronto-maxillary, frontolacrimal, fronto-ethmoidal, and frontosphenoidal sutures. In the fronto-ethmoidal suture are the anterior and posterior ethmoidal foramina, for the transmission of the corresponding ethmoidal nerves and vessels.

The *lateral wall* of the orbit (fig. 360), directed medialwards and forwards, is formed by the orbital surface of the zygomatic bone and the orbital surface

of the great wing of the sphenoidal bone; these are united by the sphenozygomatic suture which terminates below at the anterior end of the inferior orbital fissure. On the orbital process of the zygomatic bone are the orbital tubercle (Whitnall) and the orifices of one or two canals which transmit the branches of the zygomatic nerve. Between the posterior parts of the roof and the lateral wall is the superior orbital fissure. Through this fissure the oculomotor, trochlear, and abducent nerves, the three branches of the ophthalmic nerve and some filaments from the cavernous plexus of the sympathetic enter the orbital cavity. The ophthalmic veins and the recurrent meningeal branch of the lacrimal artery leave the orbit through this fissure. The lateral wall and the floor of the orbit are separated posteriorly by the inferior orbital fissure, which transmits the maxillary nerve and its zygomatic (temporomalar) branch,

FIG. 360.—The lateral wall of the right orbit.



the infra-orbital vessels, the orbital branches of the sphenopalatine ganglion, and veins which connect the inferior ophthalmic vein with the pterygoid venous plexus.

The *base* of the orbit (fig. 357), more or less quadrangular in shape, is formed above by the supra-orbital arch of the frontal bone, in which is the supra-orbital notch or foramen for the passage of the supra-orbital vessels and nerve; below by the zygomatic bone and the maxilla, united by the zygomaticomaxillary suture; laterally by the zygomatic bone and the zygomatic process of the frontal bone joined by the zygomaticofrontal suture; medially by the frontal bone and the frontal process of the maxilla united by the frontomaxillary suture. Owing to the overhang of the orbital walls in front the base of the orbit is somewhat constricted, and the greatest circumference of the cavity is about 1 cm. behind the orbital margin.

The *apex* of the orbit corresponds to the optic foramen,* a short canal through which the optic nerve and ophthalmic artery enter the orbital cavity. The sphenoidal air-sinus is on the medial side of the foramen.

* The centre of the bar of bone between the optic foramen and the superior orbital fissure is sometimes described as the apex of the orbit.

THE INTERIOR OF THE SKULL

In order to study the interior of the skull, the skull-cap should be removed by a saw-cut carried round the cranium about the level of the frontal eminences and the upper limits of the squamosal sutures, cutting the occipital bone 2·5 cm. above its external protuberance.

The Internal Surface of the Skull-cap

On the concave internal surface of the skull-cap are depressions for the convolutions of the cerebrum, and numerous furrows for the branches of the meningeal vessels. In the middle line is the sagittal sulcus, narrow in front, and broad behind; it lodges the superior sagittal sinus, and its margins afford attachment to the falx cerebri. On either side of the sulcus are several depressions for the arachnoideal granulations, and, at its posterior part, the openings of the parietal foramina when these are present. It is crossed in front by the coronal suture, and behind by the lambdoid suture, whilst the sagittal suture is in the middle line between the parietal bones.

The Internal Surface of the Base of the Skull (Basis Cranii Interna) (figs. 361, 362)

The internal surface of the base of the skull, or floor of the cranial cavity, is divided into anterior, middle, and posterior cranial fossæ.

The **anterior fossa**.—The floor of this fossa is formed by the orbital plates of the frontal bone, the lamina cribrosa of the ethmoidal bone, and the small wings and the anterior part of the body of the sphenoidal bone; it is limited behind by the posterior borders of the small wings of the sphenoidal bone and by the anterior margin of the sulcus chiasmatis. It is traversed by the fronto-ethmoidal, spheno-ethmoidal and sphenofrontal sutures. Its lateral portions form the roofs of the orbital cavities and support the frontal lobes of the cerebrum; they are convex and marked by depressions for the brain convolutions, and by grooves for branches of the meningeal vessels. The central portion of the floor corresponds with the roof of the nasal cavity, and is markedly depressed on either side of the crista galli. It presents, in the median line, from before backwards, the commencement of the frontal crest for the attachment of the falx cerebri; the foramen cæcum which frequently opens into the nasal cavity and transmits a small vein from that cavity to the superior sagittal sinus; the crista galli, the free margin of which affords attachment to the anterior end of the falx cerebri. On either side of the crista galli is the olfactory groove formed by the lamina cribrosa of the ethmoidal bone, which supports the olfactory bulb and is perforated by foramina for the transmission of the olfactory nerves; at the front part of the lamina cribrosa is the foramen for the anterior ethmoidal nerve. Lateral to the olfactory groove are the internal openings of the anterior and posterior ethmoidal foramina; the anterior, situated about the middle of the lateral margin of the olfactory groove, transmits the anterior ethmoidal nerve and vessels; the nerve runs in a groove along the lateral edge of the lamina cribrosa to the foramen above mentioned; the posterior ethmoidal foramen opens at the posterior part of this margin under cover of a projecting lamina of the sphenoidal bone, and transmits the posterior ethmoidal nerve and vessels. The anterior margin of the sulcus chiasmatis runs lateralwards to the upper margins of the optic foramina.

The **middle fossa**.—This fossa is deeper than the anterior, and is narrow in the middle, and wide at the sides of the skull. It is bounded in front by the posterior margins of the small wings of the sphenoidal bone, the anterior clinoid processes, and the ridge forming the anterior margin of the sulcus chiasmatis; behind, by the dorsum sellæ of the sphenoidal bone and the superior angles (superior margins) of the petrous portions of the temporal bones; laterally by

the temporal squamæ, the sphenoidal angles of the parietal bones, and the great wings of the sphenoidal bone. It is traversed by the squamosal, sphenoparietal, sphenosquamosal, and sphenopetrosal sutures.

The middle part of the fossa presents, in front, the sulcus chiasmatis and tuberculum sellæ; the sulcus ends on either side at the optic foramen, which transmits the optic nerve and ophthalmic artery to the orbital cavity. The anterior clinoid process is directed backwards and medialwards behind the optic foramen and gives attachment to the anterior end of the free border of the tentorium cerebelli. Behind the tuberculum sellæ is the sella turcica, the deepest part of which lodges the hypophysis and is named the fossa hypophyseos. At the lateral angles of the anterior wall of the sella turcica are the middle clinoid processes. The sella turcica is bounded posteriorly by the dorsum sellæ, the upper angles of which are surmounted by the posterior clinoid processes; these afford attachment to the lateral borders of the tentorium cerebelli, and a little below each process the side of the dorsum sellæ is notched for the passage of the abducent nerve. Lateral to the sella turcica is the carotid sulcus, which begins behind at the foramen lacerum, and ends on the medial side of the anterior clinoid process, where it is sometimes converted into a foramen (caroticoclinoid) by the union of the anterior and middle clinoid processes; the posterior part of the sulcus is bounded anterolaterally by the lingula. The carotid sulcus lodges the cavernous sinus, the internal carotid artery, and the plexus of sympathetic nerves surrounding the latter.

The lateral parts of the middle fossa are deep, and support the temporal lobes of the brain. They are marked by depressions for the brain convolutions, and are traversed by furrows for the anterior and posterior branches of the middle meningeal vessels. These furrows begin by the bifurcation of a groove which commences at the foramen spinosum and runs for about 2 cm. forwards and lateralwards on the temporal squama; the anterior furrow is directed forwards and upwards to the sphenoidal angle of the parietal bone, where it is sometimes converted into a bony canal; the posterior furrow arches backwards across the upper part of the temporal squama and passes on to the parietal bone near the middle of its lower border. In the anterior part of the fossa is the superior orbital fissure, bounded above by the small wing, below by the great wing and medially by the body, of the sphenoidal bone; it is usually completed laterally by the orbital plate of the frontal bone. It transmits to the orbital cavity the oculomotor, trochlear, and abducent nerves, the three branches of the ophthalmic nerve, and some filaments from the cavernous plexus of the sympathetic; and from the orbital cavity the recurrent meningeal branch of the lacrimal artery, and the ophthalmic veins. Behind the medial end of the superior orbital fissure is the foramen rotundum, for the exit of the maxillary nerve. Posterior and lateral to the foramen rotundum is the foramen ovale, which transmits the mandibular nerve, the accessory meningeal artery, and the lesser superficial petrosal nerve.* Medial to the foramen ovale is the foramen Vesalii which varies in size, and is often absent; when present, it opens below at the lateral side of the scaphoid fossa, and transmits a small vein. Lateral to the foramen ovale is the foramen spinosum, for the passage of the nervus spinosus and the middle meningeal artery. Medial and posterior to the foramen ovale is the foramen lacerum; in the recent state the lower part of this foramen is filled by a fibrocartilaginous plate, on the upper surface of which rests the internal carotid artery surrounded by a plexus of sympathetic nerves; the nerve of the pterygoid canal, and a meningeal branch from the ascending pharyngeal artery, pierce the fibrocartilaginous plate. On the anterior surface of the petrous portion of the temporal bone is the eminentia arcuata caused by the upward projection of the superior semicircular canal; in front of this, the depressed area forming the roof of the tympanic cavity, and the groove leading to the hiatus of the facial canal for the transmission of the greater superficial petrosal nerve and the petrosal branch of the middle meningeal artery; lateral to this groove, the smaller groove for the passage of the lesser superficial petrosal nerve; and, near the apex of the bone, the depression for the semilunar ganglion, and the internal orifice of the carotid canal.

The **posterior fossa**.—The posterior fossa, the largest and deepest, is formed by the dorsum sellæ of the sphenoidal bone, the basilar and lateral parts of the

* See footnote, p. 203.

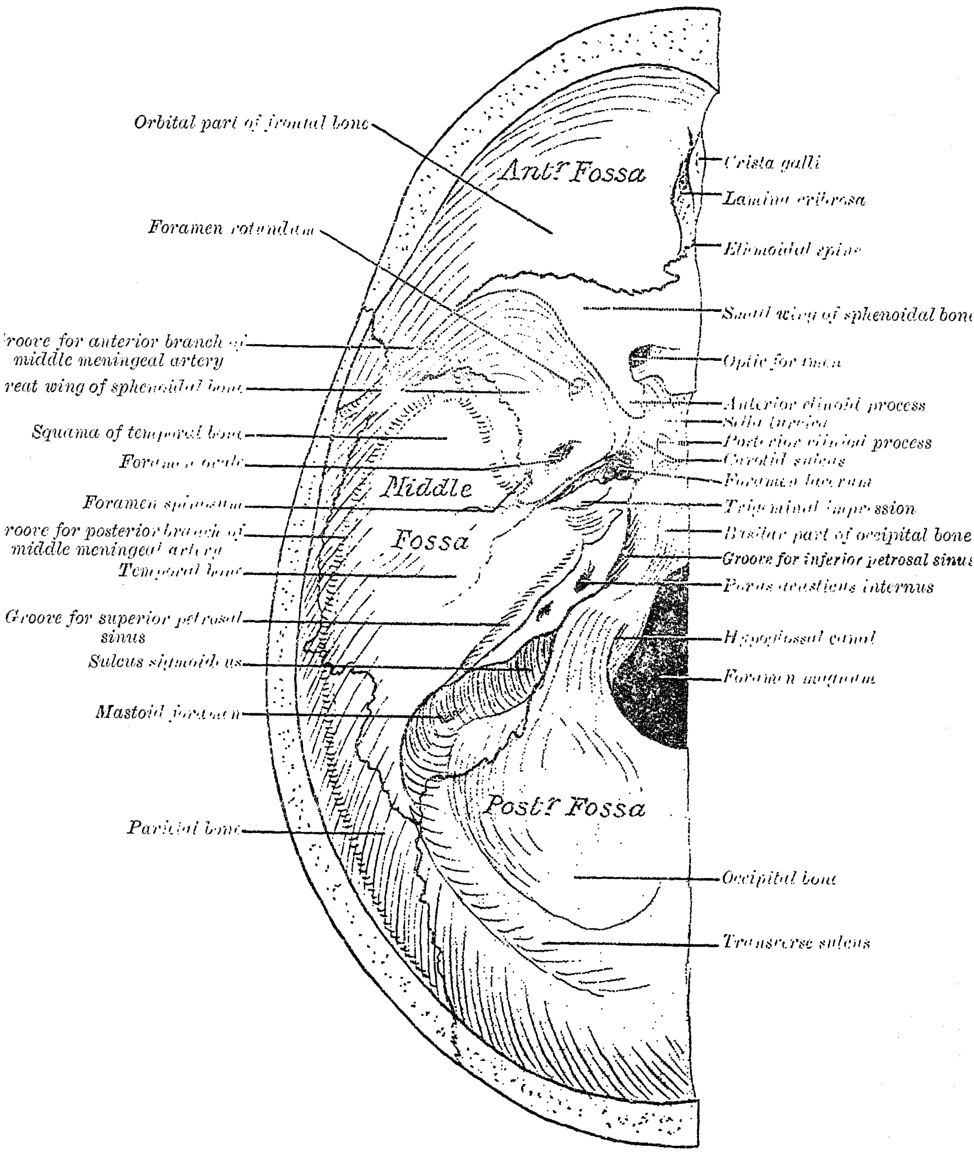
occipital bone, the petrous and mastoid portions of the temporal bones, the mastoid angles of the parietal bones, and the lower part of the squama occipitalis; it lodges the cerebellum, pons, and medulla oblongata, and is crossed by the petro-occipital, occipitomastoid, and parietomastoid sutures. It is

FIG. 361.—The internal surface of the left half of the base of the skull. (Basis cranii interna.)

separated from the middle fossa in and near the median line by the dorsum sellæ of the sphenoidal bone, and on either side by the superior angle (superior margin) of the petrous portion of the temporal bone. This angle gives attachment to the tentorium cerebelli, is grooved for the superior petrosal sinus, and is notched at its medial end for the trigeminal nerve. The posterior fossa is limited behind by the transverse sulci of the occipital bone. In its centre is the foramen magnum, and on either side of this foramen is a rough tubercle for the attachment of the alar ligaments; a little above this tubercle is the

hypoglossal canal which transmits the hypoglossal nerve and a meningeal branch from the ascending pharyngeal artery. In front of the foramen magnum the basilar portion of the occipital bone and the posterior part of the body of the sphenoidal bone form a grooved sloping surface which supports the medulla

Fig. 362.—Key to fig. 361.



oblongata and pons; in the young skull these bones are joined by a synchondrosis. This grooved surface is separated on either side from the petrous portion of the temporal bone by the petro-occipital fissure, which is occupied in the recent state by a plate of cartilage; the fissure is continuous behind with the jugular foramen, and its margins are grooved for the inferior petrosal sinus. The jugular foramen is situated between the lateral part of the occipital bone and the petrous part of the temporal bone. The anterior portion of this foramen transmits the inferior petrosal sinus; the posterior portion, the transverse sinus

The *medial surface* (fig. 315) is convex, perforated by numerous apertures, and traversed by longitudinal grooves for the lodgment of vessels. The *lateral surface* is concave (fig. 316), and forms part of the inferior meatus of the nasal cavity. The *superior border* is thin and irregular, and may be divided into three portions: of these, the anterior articulates with the crista conchalis of the maxilla, and the posterior with the crista conchalis of the palatine bone. The middle portion presents three processes, which vary in size and form. Of these, the *lacrimal process* is small and pointed and is situated at the junction of the anterior one-fourth with the posterior three-fourths of the bone: it articulates, by its apex, with the descending process of the lacrimal bone (fig. 314), and, by its margins, with the edges of the nasolacrimal groove on the medial

Fig. 315.—The right inferior nasal concha. Medial aspect.

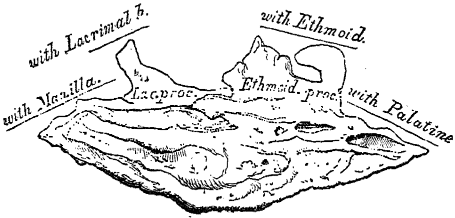
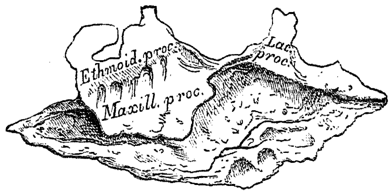


Fig. 316.—The right inferior nasal concha. Lateral aspect.



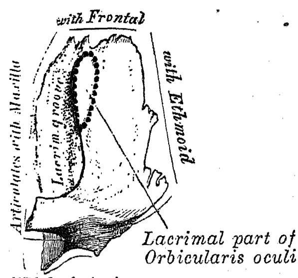
surface of the body of the maxilla, and thus assists in forming the canal for the nasolacrimal duct. Behind this process a thin plate, the *ethmoidal process*, ascends to join the uncinate process of the ethmoid (fig. 314). From the middle part of the superior border a thin lamella, the *maxillary process*, curves downwards and lateralwards; it articulates with the maxilla and the maxillary process of the palatine bone, and forms a part of the medial wall of the maxillary sinus (fig. 328). The *inferior border* is free, thick, and spongy in structure, more especially in the middle of the bone. Both *ends* are more or less pointed, the posterior being the more tapered.

Ossification.—The inferior nasal concha is ossified from one centre; this appears about the fifth month of fœtal life in the maxilloturbinal cartilage which is the incurved lower border of the lateral wall of the nasal capsule. It is detached from the remainder of the nasal capsule during ossification.

The Lacrimal Bones (Ossa Lacrimalia)

The **lacrimal bones**, the smallest and most fragile of the cranial bones, are situated at the front parts of the medial walls of the orbits (figs. 319, 328). Each lacrimal bone has two surfaces and four borders. The *lateral or orbital surface* (fig. 317) is divided by a vertical ridge, the *posterior lacrimal crest*. In front of this crest is a vertical groove, the *lacrimal groove*. The anterior border of this groove articulates with the posterior border of the frontal process of the maxilla to complete the *lacrimal fossa* for the lodgement of the lacrimal sac. The medial wall of the lacrimal groove is prolonged downwards under the name of the *descending process*. This process assists in forming the bony canal for the nasolacrimal duct by articulating with the lips of the sulcus lacrimalis of the maxilla, and with the lacrimal process of the inferior nasal concha. The portion behind the crest is smooth, and forms a part of the medial wall of the orbit. The crest, with a part of the orbital surface immediately posterior to it, gives origin to the lacrimal part of the Orbicularis oculi.

Fig. 317.—The left lacrimal bone. Lateral aspect. (Enlarged.)

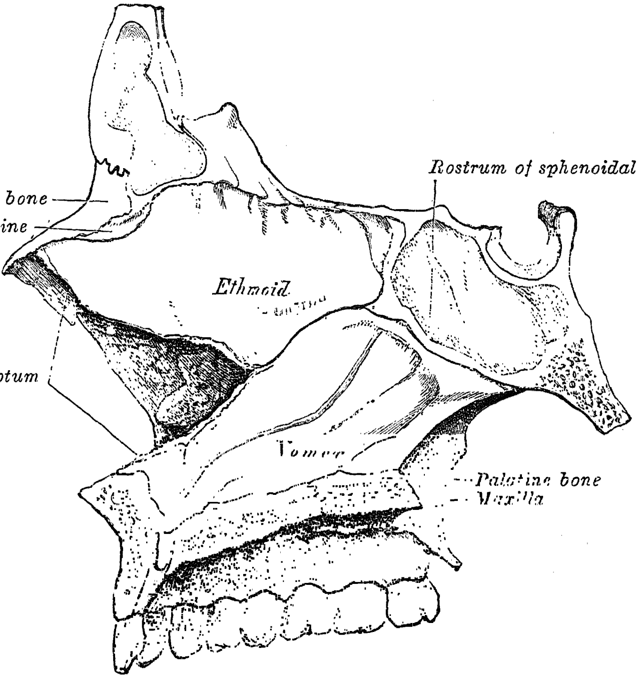


The crest ends below in a small hook, the *lacrimal hamulus*, which articulates with the lacrimal tubercle of the maxilla and completes the upper orifice of the

Each nasal cavity has a roof, a floor, and a medial and a lateral wall.

The *roof* (figs. 365, 366) is horizontal in its central part, but slopes downwards in front and behind; it is formed in front by the nasal bone and the frontal spine; in the middle, by the lamina cribrosa of the ethmoidal bone; and behind, by the body of the sphenoidal bone, the sphenoidal concha, the ala of the vomer and the sphenoidal process of the palatine bone. In the lamina cribrosa are the foramina for the olfactory nerves, and in front of these is the foramen for the anterior ethmoidal nerve; in the posterior part of the roof is the opening into the sphenoidal air-sinus.

Fig. 364.—The medial wall of the left nasal cavity.



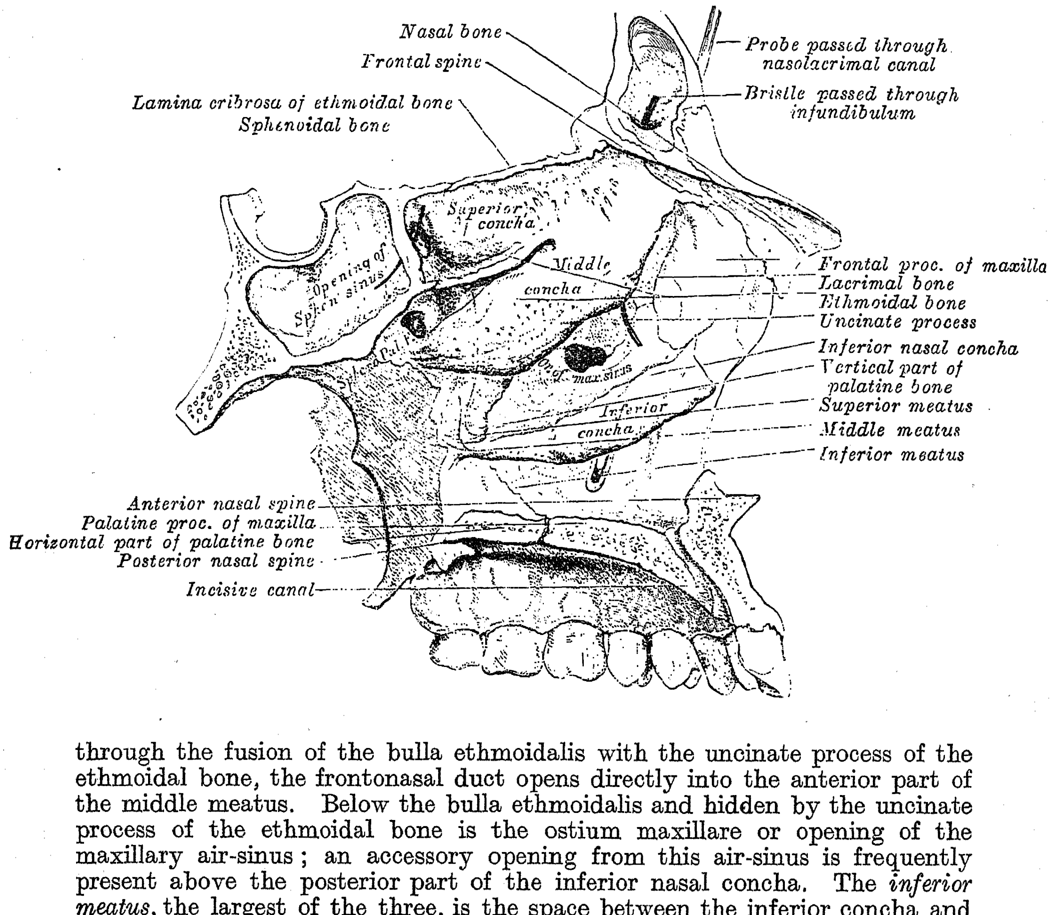
The *floor*, flattened from before backwards and concave from side to side, is formed by the palatine process of the maxilla and the horizontal part of the palatine bone; near its anteromedial angle is the opening of the incisive canal.

The *medial wall*, or *septum nasi* (fig. 364), is frequently deflected to one or other side, more often to the left than to the right. It is formed, in front, by the crest of the nasal bones and the frontal spine; in the middle, by the lamina perpendicularis of the ethmoidal bone; behind, by the vomer and by the rostrum of the sphenoidal bone; below, by the crest of the maxillæ and palatine bones. In front is a large, triangular notch which is filled by the cartilage of the septum; behind, is the free edge of the vomer. The septum nasi is marked by furrows for vessels and nerves, and the vomer is grooved for the nasopalatine nerve also.

The *lateral wall* (figs. 365, 366) is formed, in front, by the nasal bone, the frontal process of the maxilla, and the lacrimal bone; in the middle, by the ethmoidal bone, the maxilla, and the inferior nasal concha; behind, by the vertical part of the palatine bone, and the medial pterygoid lamina of the sphenoidal bone. On this wall are three irregular, anteroposterior passages, termed the superior, middle, and inferior meatuses of the nose. The *superior meatus*, the smallest of the three, is between the superior and middle nasal conchæ; the sphenopalatine foramen opens into it behind, and the posterior ethmoidal air-sinuses

in front. Above and behind the superior concha is a triangular depression named the spheno-ethmoidal recess into which the sphenoidal air-sinus opens. The *middle meatus* is between the middle and inferior conchæ, and extends from the anterior to the posterior end of the latter. The lateral wall of this meatus can be satisfactorily studied only after the removal of the middle concha. On it is a curved fissure, the hiatus semilunaris, limited below by the edge of the uncinate process of the ethmoidal bone, and above by an elevation named the bulla ethmoidalis; the middle ethmoidal air-sinuses are contained within this bulla, and open on, or near to it. Through the hiatus semilunaris the meatus opens into a curved passage termed the infundibulum; the infundibulum communicates in front with the anterior ethmoidal air-sinuses, and in rather more than fifty per cent. of skulls is continuous above with the frontonasal duct which opens into the frontal air-sinus; when this continuity fails

FIG. 365.—The roof, floor, and lateral wall of the left nasal cavity.



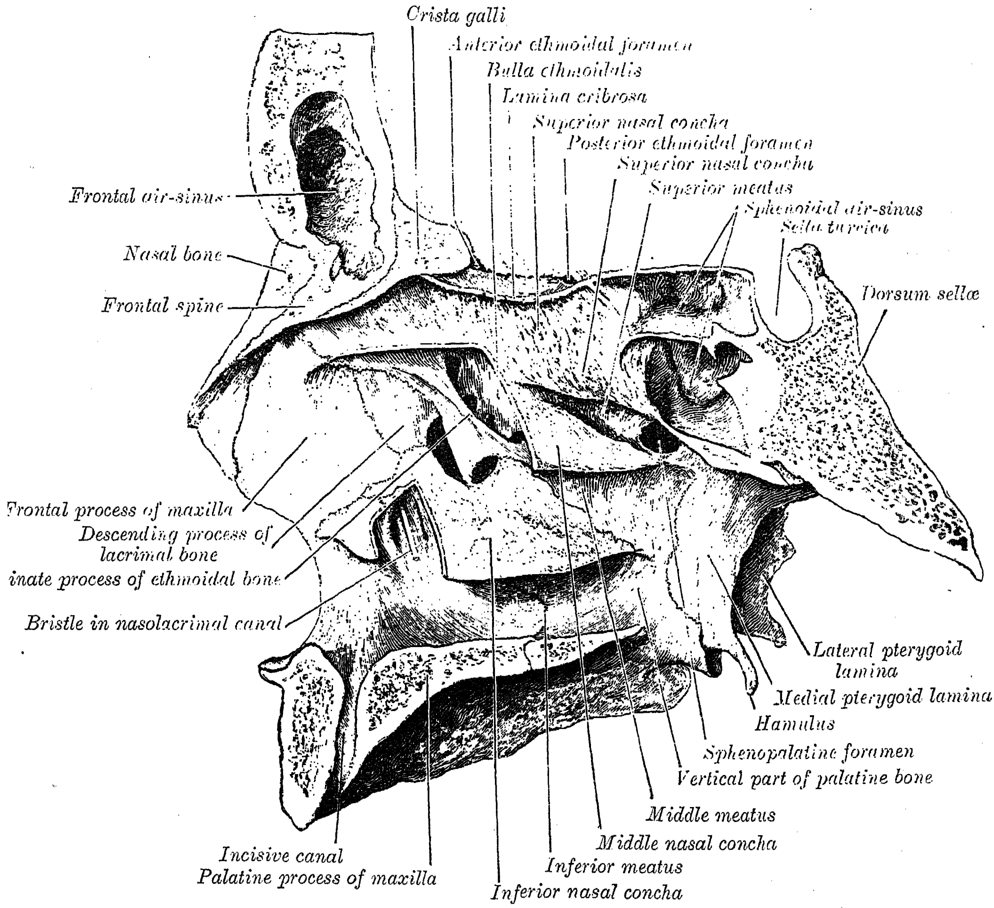
through the fusion of the bulla ethmoidalis with the uncinate process of the ethmoidal bone, the frontonasal duct opens directly into the anterior part of the middle meatus. Below the bulla ethmoidalis and hidden by the uncinate process of the ethmoidal bone is the ostium maxillare or opening of the maxillary air-sinus; an accessory opening from this air-sinus is frequently present above the posterior part of the inferior nasal concha. The *inferior meatus*, the largest of the three, is the space between the inferior concha and the floor of the nasal cavity. It extends almost the entire length of the lateral wall of the nose, is broader in front than behind, and presents anteriorly the lower orifice of the nasolacrimal canal.

The *apertura piriformis*, or *anterior nasal aperture* (fig. 356), is bounded above by the inferior borders of the nasal bones; laterally by the thin, sharp margins which separate the anterior from the nasal surfaces of the maxillæ; and below by the same margins, where they curve medialwards to join each other at the anterior nasal spine. In the recent state it is much contracted by the lateral and alar cartilages of the nose.

The *choanæ* or *posterior nasal apertures* are separated from one another by the posterior border of the vomer; each is bounded above by the ala of the

vomer and the vaginal process of the medial pterygoid lamina ; below, by the posterior border of the horizontal part of the palatine bone ; laterally, by the medial pterygoid lamina.

FIG. 366.—The lateral wall of the right nasal cavity, with parts of the middle and inferior nasal conchæ removed.



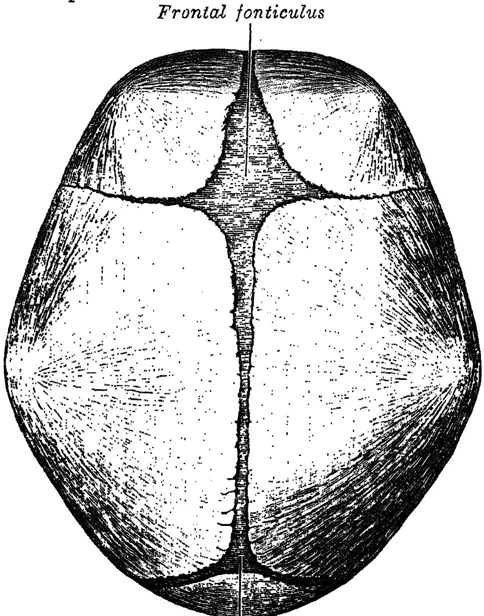
THE DIFFERENCES IN THE SKULL DUE TO AGE

At birth the skull is large in proportion to the other parts of the skeleton, but the base is short and narrow in proportion to the vault ; the facial portion is small and equals only about one-eighth of the bulk of the cranium as compared with one-half in the adult. The frontal and parietal tuberosities or eminences are prominent, and when the skull is viewed from above it presents a pentagonal outline with its greatest width at the parietal tuberosities (fig. 367) ; on the other hand, the glabella, superciliary arches, and mastoid processes are not developed. Ossification of the skull bones is not completed, and many of them—e.g. the occipital, temporals, sphenoidal, frontal, and mandible—consist of more than one piece. Unossified membranous intervals, termed fonticuli (fontanelles), are seen at the angles of the parietal bones ; these fonticuli are six in number ; two, the frontal and occipital, are situated in the middle line, and two, the sphenoidal and mastoid, on either side.

The *frontal or anterior fonticulus* (fig. 367) is the largest, and is placed at the junction of the sagittal, coronal, and frontal sutures ; it is lozenge-shaped, and measures about 4 cm. in its anteroposterior and 2·5 cm. in its transverse diameter. The *occipital or posterior fonticulus* (fig. 367) is triangular in form and is situated

at the junction of the sagittal and lambdoid sutures. The *sphenoidal and mastoid fonticuli* (fig. 368) are small, irregular in shape, and correspond respectively with the sphenoidal and mastoid angles of the parietal bones. An additional fonticulus is sometimes seen in the sagittal suture at the region of the obelion.

FIG. 367.—The skull at birth, showing the frontal and occipital fonticuli. Superior aspect.

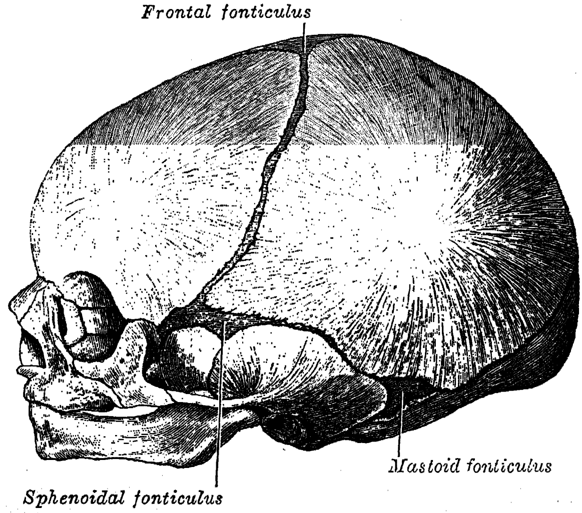


The fonticuli are usually closed by the growth and extension of the bones which surround them, but sometimes they are the sites of separate centres of ossification which develop into sutural bones. The occipital and sphenoidal fonticuli are obliterated within two or three months after birth; the mastoid fonticulus is usually closed about the end of the first year, and the frontal fonticulus about the middle of the second year.

The smallness of the face at birth is mainly accounted for by the rudimentary condition of the mandible and maxillæ, the non-eruption of the teeth, and the small size of the maxillary air-sinuses and nasal cavities. At birth the nasal cavities lie almost entirely between the orbits, and the lower border of the anterior nasal aperture is only a little below the level of the orbital floor. With the eruption of the deciduous teeth there is an enlargement of the face and jaws, and these changes are still more marked after the second dentition.

The skull grows rapidly from birth to the seventh year; at the latter age the lamina cribrosa of the ethmoidal bone, the foramen magnum, and the petrous parts of the temporal bones have reached their full size, and the orbital cavities are

FIG. 368.—The skull at birth, showing the sphenoidal and mastoid fonticuli. Left lateral aspect.



only a little smaller than those of the adult. Growth is slow from the seventh year until the approach of puberty, when a second period of increased activity

occurs: this results in an enlargement in all directions, but especially in the frontal and facial regions, where it is associated with the development of the air-sinuses.

Obliteration of the sutures of the vault of the skull takes place as age advances. It may commence between the ages of thirty and forty on the inner surface, and about ten years later on the outer surface of the skull, but the times at which the sutures are closed are subject to great variations. Obliteration usually occurs first in the lower part of the coronal suture, next in the posterior part of the sagittal suture, and then in the lambdoid suture.

In old age the skull generally becomes thinner and lighter, but in a small proportion of cases it increases in thickness and weight. The most striking feature of the senile skull is the diminution in the size of the mandible and maxillæ consequent on the loss of the teeth and the absorption of the alveolar processes. This is associated with a marked reduction in the vertical measurement of the face and with an alteration in the angles of the mandible.

The Sex Differences in the Skull

Until the age of puberty there is little difference between the skull of the female and that of the male. The skull of an adult female is as a rule lighter and smaller, and its capacity is about 10 per cent. less, than that of the male. Its walls are thinner and its muscular ridges less marked; the glabella, superciliary arches, and mastoid processes are less prominent, and the corresponding air-sinuses are small or rudimentary. The upper margin of the orbit is sharp, the forehead vertical, the frontal and parietal tuberosities prominent, and the vault somewhat flattened. The contour of the face is rounder, the facial bones are smoother, and the mandible and maxillæ and their contained teeth smaller. Speaking generally, more of the infantile characteristics are retained in the skull of the adult female than in that of the adult male. A well-marked male or female skull can easily be recognised as such, but in some skulls the respective characteristics are so indistinct that the determination of the sex may be difficult or impossible.*

Craniology

Skulls vary in size and shape, and the term craniology is applied to the study of these variations.

The *capacity* of the cranial cavity constitutes a good index of the size of the brain which it contained, and is most conveniently arrived at by filling the cavity with shot and measuring the contents in a graduated vessel. Skulls may be classified according to their capacities as follows:

1. *Microcephalic*, with a capacity of less than 1350 c.cm.—e.g. those of native Australians and Andaman Islanders.
2. *Mesocephalic*, with a capacity of from 1350 c.cm. to 1450 c.cm.—e.g. those of African negroes and Chinese.
3. *Megacephalic*, with a capacity of over 1450 c.cm.—e.g. those of Europeans, Japanese and Eskimos.

In comparing the shape of one skull with that of another it is necessary to adopt some definite position in which the skulls should be placed during the process of examination. They should be so placed that a line carried through the lower margin of the orbit and upper margin of the opening of the external acoustic meatus is in the horizontal plane. The normæ of one skull can then be compared with those of another, and the differences in contour and surface-form noted. Further, it is necessary that the various linear measurements used to determine the shape of the skull should be made between definite and easily localised points on its surface. The principal points may be divided into two groups: (1) those in the median plane, and (2) those on either side of it (fig. 369).

The **points in the median plane** are the:

Pogonion. The most prominent point of the chin.

Alveolar point or *prosthion.* The central point of the anterior margin of the upper alveolar arch.

Akanthion. The tip of the anterior nasal spine.

Subnasal point. The middle of the lower border of the anterior nasal aperture, at the base of the anterior nasal spine.

Rhinion. The most prominent point of the internasal suture.

Nasion. The central point of the frontonasal suture.

Glabella. The point in the middle line at the level of the superciliary arches.

* Some additional differences between the male and female skull are given by Professor F. G. Parsons and Mrs. Lucas Keene, *Journal of Anatomy*, vol. liv. 1919.

Ophryon. The point in the middle line of the forehead at the level where the temporal lines most nearly approach each other.

Bregma. The meeting point of the coronal and sagittal sutures.

Obelion. A point in the sagittal suture on a level with the parietal foramina.

Lambda. The point of junction of the sagittal and lambdoid sutures.

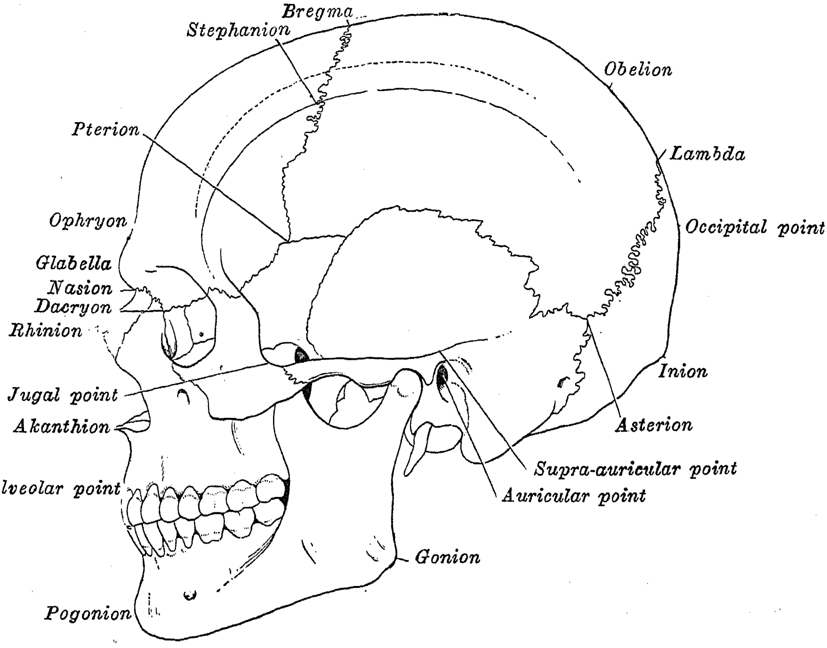
Occipital point. The point in the middle line of the occipital bone farthest from the glabella.

Inion. The external occipital protuberance.

Opisthion. The mid-point of the posterior margin of the foramen magnum.

Basion. The mid-point of the anterior margin of the foramen magnum.

FIG. 369.—An outline of the left side of the skull.



The **points on either side of the median plane** are the:

Gonion. The outer margin of the angle of the mandible.

Jugal point. The angle between the temporal border of the zygomatic bone and the upper border of the zygomatic arch.

Dacryon. The point of union of the anterosuperior angle of the lacrimal with the frontal bone and the frontal process of the maxilla.

Pterion. The point where the great wing of the sphenoidal bone joins the sphenoidal angle of the parietal.

Stephanion. The point where the temporal line intersects the coronal suture.

Auricular point. The centre of the orifice of the external acoustic meatus.

Supra-auricular point. A point on the posterior root of the zygomatic arch, above the middle of the orifice of the external acoustic meatus.

Asterion. The point of meeting of the lambdoid, masto-occipital, and mastoparietal sutures.

The *horizontal circumference* of the cranium is measured in a plane passing through the glabella in front, and the occipital point behind; it averages about 50 cm. in the female and 52·5 cm. in the male.

The *occipitofrontal or longitudinal arc* is measured from the nasion over the middle line of the vertex to the opisthion, while the *basinasal length* is the distance between the basion and the nasion. These two measurements, plus the anteroposterior diameter of the foramen magnum, represent the *vertical circumference* of the cranium.

The *length* is measured from the glabella to the occipital point, while the *breadth* or greatest transverse diameter is usually found a little above and behind the opening of the external acoustic meatus. The proportion of breadth to length $\frac{\text{breadth} \times 100}{\text{length}}$ is termed the *cephalic index* or *index of breadth.*

The *height* is measured from the basion to the bregma, and the proportion of height to length $\frac{\text{height} \times 100}{\text{length}}$ constitutes the *vertical or height index.*

In studying the face the principal points to be noticed are the proportion of its length to its breadth, the shape of the orbits and of the anterior nasal aperture, and the degree of projection of the jaws.

The *length of the face* is measured from the nasion to the lower margin of the mandible, or, if the mandible be wanting, to the alveolar point; its *width* is the distance between the zygomatic arches. By comparing the length with the width of the face, skulls may be divided into two groups; *dolichofacial* (long-faced) and *brachyfacial* (short-faced).

The *orbital index* signifies the proportion which the orbital height bears to the orbital width, thus:

$$\frac{\text{orbital height} \times 100}{\text{orbital width}}$$

The *nasal index* expresses the proportion which the width of the anterior nasal aperture bears to the height of the nose, the latter being measured from the nasion to the subnasal point, thus:

$$\frac{\text{nasal width} \times 100}{\text{nasal height}}$$

The degree of projection of the jaws is determined by the *gnathic or alveolar index*, which represents the proportion between the basi-alveolar and basinasal lengths, thus:

$$\frac{\text{basi-alveolar length} \times 100}{\text{basinasal length}}$$

The *dental index* is arrived at by comparing the *dental length* (i.e. the distance between the anterior surface of the first premolar and the posterior surface of the third molar tooth of the maxilla) with the basinasal length, thus:

$$\frac{\text{dental length} \times 100}{\text{basinasal length}}$$

The following table, modified from that given by Duckworth,* illustrates how some of these indices may be utilised in the classification of skulls:

Index.	Classification.	Nomenclature.	Examples.
1. Cephalic	Below 75	Dolichocephalic	Kaffirs and Native Australians
	Between 75 and 80	Mesaticephalic	Europeans and Chinese
	Above 80	Brachycephalic	Mongolians and Andamans
2. Orbital	Below 84	Microseme	Tasmanians and Native Australians
	Between 84 and 89	Mesoseme	Europeans
	Above 89	Megaseme	Chinese and Polynesians
3. Nasal	Below 48	Leptorhine	Europeans
	Between 48 and 53	Mesorhine	Japanese and Chinese
	Above 53	Platyrhine	Negroes and Native Australians
4. Gnathic	Below 98	Orthognathous	Europeans
	Between 98 and 103	Mesognathous	Chinese and Japanese
	Above 103	Prognathous	Native Australians

Applied Anatomy.—Occasionally a protrusion of the brain or its membranes may take place through one of the sutures, owing to non-closure. When the protrusion consists of membranes only, and is filled with cerebrospinal fluid, it is called a *meningocele*; when it consists of brain as well as membranes, it is termed an *encephalocele*. These malformations are usually found in the middle line, and most frequently at the back of the head, the protrusion taking place between the centres of ossification of the occipital squama (see p. 200.) They generally occur through the upper part of the vertical fissure, which is the last to close, but not uncommonly through the lower part, when the foramen magnum may be incomplete. More rarely these protrusions are met with in other situations, as in the sagittal, lambdoid, and other sutures, or through abnormal gaps at the sides or base of the skull.

* W. L. H. Duckworth, *Morphology and Anthropology*, Cambridge University Press.

The chief function of the skull is to protect the brain, and therefore those portions of the skull which are most exposed to external violence are thicker than those which are shielded from injury by overlying muscles. Thus, the skull-cap is thick and dense, whereas the temporal squamæ, being protected by the Temporales muscles, and the inferior occipital fossæ, being shielded by the muscles at the back of the neck, are thin and fragile. Fracture of the skull is further prevented by its elasticity, its rounded shape, and its construction of a number of secondary elastic arches, each made up of a single bone. The manner in which vibrations are transmitted through the bones of the skull is also of importance as regards its protective mechanism, at all events as far as the base is concerned. In the vault, the bones being of a fairly equal thickness and density, vibrations are transmitted in a uniform manner in all directions, but in the base, owing to the varying thickness and density of the bones, this is not so; and therefore in this situation there are special buttresses which serve to carry the vibrations in certain definite directions. At the front of the skull, on either side, is the ridge which separates the anterior from the middle fossa of the base; and behind, the ridge or buttress which separates the middle from the posterior fossa; and if any violence is applied to the vault, the vibrations would be carried along these buttresses to the sella turcica, where they meet. This part has been termed the 'centre of resistance,' and here there is a special protective mechanism to guard the brain. The subarachnoid cavity at the base of the brain is dilated, and the cerebrospinal fluid which fills it acts as a water-cushion to shield the brain from injury. In like manner, when violence is applied to the base of the skull, as in falls upon the feet, the vibrations are carried backwards through the occipital crest, and forwards through the basilar part of the occipital and body of the sphenoidal bone to the vault of the skull.

Fractures of the skull are best considered as affecting either the vault or the base. Fractures of the vault generally involve the whole thickness of the bone; but sometimes the inner table alone is fractured, and portions of it driven inwards. In fractures of the skull, and especially in punctured fractures, the inner table is more splintered and comminuted than the outer, and this is due to several causes. It is thinner and more brittle; the force of the violence as it passes inwards becomes broken up and is more diffused by the time it reaches the inner table; the bone being in the form of an arch bends as a whole and spreads out, and thus presses the particles together on the convex surface of the arch, i.e. the outer table, and forces them asunder on the concave surface or inner table; and, lastly, there is nothing firm under the inner table to support it and oppose the force. Fractures of the vault may be either simple, or starred and comminuted, and the fragments may be depressed or elevated. Cases of fracture with elevation of the fractured portion are uncommon, and can only be produced by direct wound. In comminuted fracture, a portion of the skull is broken into several pieces, the lines of fracture radiating from a centre where the chief impact of the blow was felt; if the fracture is also depressed, a fissure circumscribes the radiating lines, enclosing a portion of the skull. If this area is circular it is termed a 'pond' fracture, and has probably been caused by a round instrument, as a life-preserver or hammer; if elliptical in shape it is termed a 'gutter' fracture, and owes its shape to the instrument which has produced it, as a poker. Fracture of the outer table alone may occur in the region of the frontal air-sinuses where the two tables are completely separated.

Fractures of the base of the skull may be produced by *indirect* or *direct* violence.

I. In cases of the former class the violence is applied to the vertex or some part of the cranial convexity, as when a person falls from a height on to his head and a fracture of the base results. The mechanism of this form of fracture is explained, (*a*) by extension of a fissure from the vertex to the base, or (*b*) by compression causing bursting to take place at a weak point in the base.

II. Direct violence may be applied to the base of the skull in several different ways: by the impact of the vertebral column against the condyles of the occipital bone, in falls on the buttocks or feet; by the condyle of the mandible being driven against the mandibular fossa, in blows or falls on the chin; by the thrusting of a pointed instrument through the orbit or nose; by gunshot wounds through the mouth; and by a fall or a stab on the back of the head.

In the majority of cases the fracture is compound. The most common place for fracture of the base to occur is through the middle fossa, and here the fissure usually takes a fairly definite course. Starting from the point struck, which is generally somewhere in the neighbourhood of the parietal eminence, it runs downwards through the parietal and the temporal squama and across the petrous portion, frequently traversing and implicating the internal acoustic meatus, to the foramen lacerum. From this it may pass across the body of the sphenoidal bone, through the sella turcica, to the foramen lacerum of the other side, and may indeed travel round the whole cranium so as completely to separate the anterior from the posterior part. The course of the fracture explains the symptoms to which fracture in this region may give rise: thus if the fissure pass across the internal acoustic meatus injury to the facial and acoustic nerves may result, with consequent facial paralysis and deafness; if the fissure extends through the semicircular canals giddiness will be complained of, especially on turning the head sideways; or the tubular prolongation of the arachnoid around the nerves in the meatus may be torn and thus permit of the escape of the cerebrospinal fluid should there be a communication between the

internal ear and the tympanic cavity together with rupture of the tympanic membrane, as is frequently the case: again, if the fissure pass across the sella turcica, and the mucoperiosteum covering the under surface of the body of the sphenoidal bone is torn, blood will find its way into the pharynx and be swallowed, and after a time vomiting of blood will result. Fractures of the anterior fossa, involving the bones forming the roof of the orbit and nasal cavity, are generally the result of blows on the forehead; but fracture of the lamina cribrosa of the ethmoid may be a complication of fracture of the nasal bone. When the fracture implicates the roof of the orbit, the blood finds its way into this cavity, and travelling forwards, appears as a subconjunctival ecchymosis. If the roof of the nasal cavity be fractured, the blood escapes from the nose. In rare cases there may be also escape of cerebrospinal fluid from the nose should the dura mater and arachnoid have been torn. In fractures of the posterior fossa, extravasation of blood may appear at the nape of the neck, beneath the muscles attached to the superior nuchal line of the occipital bone.

Deformities of the skull.—General enlargement of the skull, producing characteristic deformities of various types, occurs in certain rare diseases such as ostitis deformans, acromegaly, and leontiasis ossea; it also is present in the much commoner disorders, rickets and hydrocephalus. In rickety cases the skull becomes enlarged from the formation of periosteal outgrowths of soft tissue on the outer side of the skull. These deposits are very rich in blood-vessels, and occur between the ridges of the cranial bones and their centres of ossification, and are symmetrically arranged—often about the anterior fontanelle; *Parrot's nodes,* which are local thickenings of the diplöe or of the outer table are often associated with rickets, especially when congenital syphilis coexists. The anterior fontanelle itself, instead of closing about the middle of the second year, remains patent until the third or even the sixth year. The general shape of the skull alters. The forehead is high and square, with prominent frontal eminences, and the head tends to be cubical or box-shaped; the enlargement of the head in rickets appears to be greater than it really is because the development of the facial bones is retarded. The base of the nose may appear sunken, from retarded development of the basis cranii. In congenital hydrocephalus, or enlargement of the head due to the presence of excess of fluid in the ventricles of the brain, the cranium becomes globular, and its bones are thin and often widely separated.

The bones of the face are sometimes fractured as the result of direct violence. Those most commonly broken are the nasal bones and the mandible; the latter is by far the most frequently fractured of all the facial bones. Fracture of the *nasal bone* is for the most part transverse, and takes place about 1·25 cm. from the free margin. The broken portion may be displaced backwards or more generally to one side by the force which produced the lesion. The *zygomatic bone* is probably never broken alone—that is to say, without fracture of some of the other bones of the face. The *zygomatic arch* is occasionally fractured, and when this occurs as a result of direct violence the fragments may be displaced inwards. Fractures of the *maxilla* may vary much in degree, from the chipping off of a portion of the alveolar arch to an extensive comminution of the whole bone from severe violence, as the kick of a horse. The most common situation for a fracture of the *mandible* is in the neighbourhood of the canine tooth, as at this spot the bone is weakened by the deep socket for the root of this tooth; it is next most frequently fractured at the angle; then at the symphysis; and finally the neck of the condyle or the coronoid process may be broken. Occasionally a double fracture may occur, one in either half of the bone. The fractures are usually compound, from laceration of the mucous membrane covering the gums. Displacement readily occurs and is difficult to rectify; it results in inequality in the line of the teeth and is commonly due to the muscles attached in the region of the symphysis dragging this portion downwards.

In the operation of excision of the maxilla, the central incisor tooth having been extracted the incision is begun just below the medial canthus of the eye and passes along the side of the nose round the ala and down the middle line of the upper lip into the mouth. A second incision is made from the commencement of the first along the lower border of the orbit as far as the prominence of the zygomatic bone. The flap thus formed is reflected, so as to expose the bone. The periosteum attached along the lower margin of the orbit is now to be incised, and the periosteum covering the floor of the orbit is raised from the bone, for in all cases it is essential that this fibrous layer should not be removed. The mouth is now widely opened with a gag, and the mucous membrane covering the hard palate incised down to the bone in the middle line, and the soft palate separated from the hard. The surgeon having first separated the ala of the nose from its bony attachment, proceeds to divide the connexions of the maxilla with the other bones of the face. They are (1) the junction with the zygomatic bone, the line of section being carried into the inferior orbital fissure; (2) the frontal process of the maxilla; a small portion of its upper extremity, connected with the nasal bone in front, the lacrimal bone behind, and the frontal bone above, being left; (3) the connexion with the opposite maxilla and with the palatine, are broken through. The bone is now firmly grasped and the remaining attachments of the orbital plate with the ethmoid, and of the back of the bone with the palatine are broken through. Occasionally the orbital plate can be saved, and this should always be done if possible, as it prevents lowering of the eyeball and consequent double vision. A horizontal saw-cut should then be made just below the infra-orbital foramen.

THE EXTREMITIES

The extremities or limbs are four in number: a *superior pair*, subservient mainly to prehension; and an *inferior pair*, intended for support and locomotion. Both pairs are constructed after a common type, but certain functional differences are observed between them.

The bones by which the upper and lower limbs are attached to the trunk constitute respectively the shoulder- and pelvic girdles. The *shoulder-girdle* or *girdle of the superior extremities* is formed by the scapulæ and clavicles, and is imperfect in front and behind. In front, however, it is completed by the upper end of the sternum, with which the medial ends of the clavicles articulate. Behind, it is widely imperfect, the scapulæ being connected to the trunk by muscles only. The *pelvic girdle* or *girdle of the inferior extremities* is formed by the hip-bones which articulate with each other in front at the symphysis pubis. It is imperfect behind, but the gap is filled by the upper part of the sacrum. The pelvic girdle, with the sacrum, is a complete ring, massive and comparatively rigid, in marked contrast to the lightness and mobility of the shoulder-girdle.

THE BONES OF THE SUPERIOR EXTREMITY

The Scapula

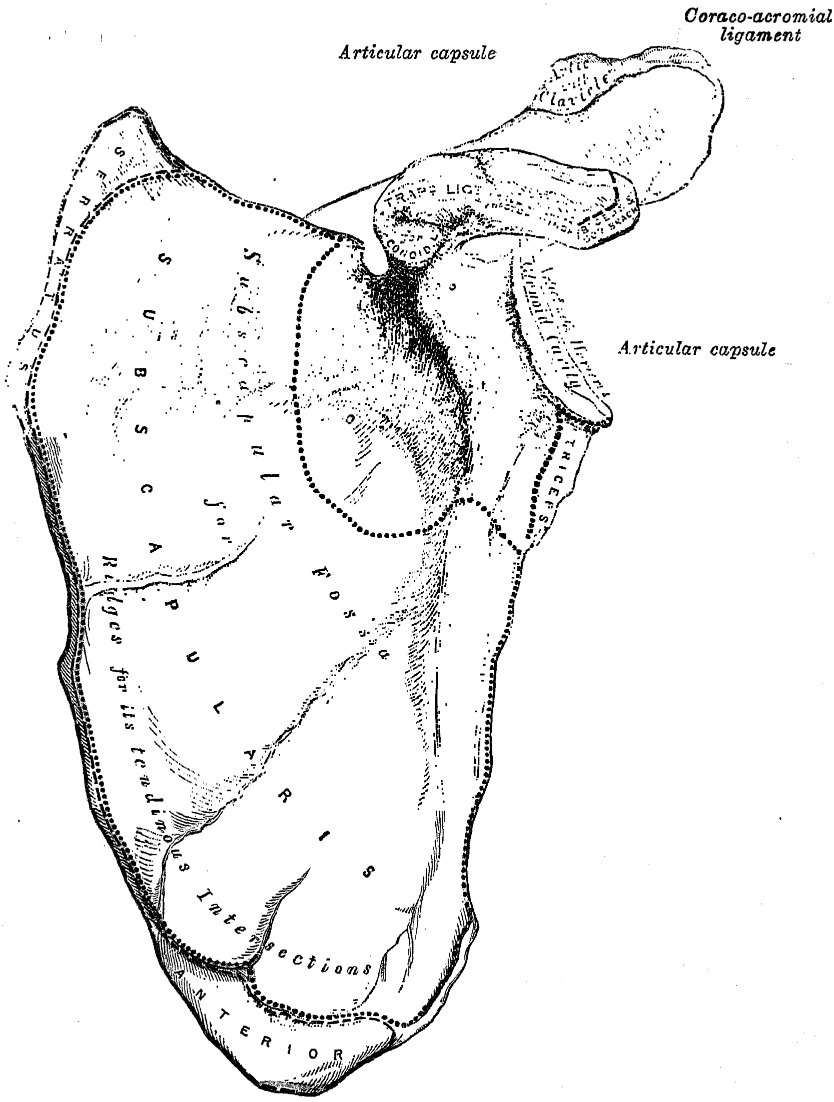
The **scapula** or shoulder-blade is a flat, triangular bone, with two surfaces, three processes, three borders, and three angles. On the lateral angle is a shallow concavity, the *glenoid cavity*, for articulation with the head of the humerus.

The *costal surface* (fig. 370) presents a broad cavity, the *subscapular fossa*, the medial two-thirds of which are marked by several oblique ridges running lateralwards and upwards. The ridges give attachment to the tendinous intersections, and the surfaces between them to the fleshy fibres, of the Subscapularis; the lateral one-third of the fossa is smooth and in contact with this muscle. The fossa is separated from the vertebral border by smooth triangular areas at the medial and inferior angles of the bone, and in the interval between the angles by a narrow ridge; these triangular areas and the intervening narrow ridge afford attachment to the Serratus anterior. At the upper part of the fossa the bone is bent on itself along a line corresponding with the attached margin of the spine.

The *dorsal surface* (fig. 371) is arched from above downwards, and is subdivided into two fossæ by a projecting plate of bone, the *spine*; the portion above the spine is called the supraspinatous fossa, and that below it the infraspinatous fossa. The *supraspinatous fossa* is concave and smooth; its medial two-thirds give origin to the Supraspinatus. The *infraspinatous fossa* is much larger than the preceding; towards its vertebral margin a shallow concavity is present at its upper part; the central part is convex, while that near the axillary border is deeply grooved. From the medial two-thirds of the fossa the Infraspinatus takes origin; the lateral one-third is in contact with this muscle. From the lower part of the glenoid cavity an elevated ridge runs downwards and backwards and reaches the vertebral border, about 2·5 cm. above the inferior angle; it gives attachment to a fibrous septum which separates the Infraspinatus from the Teres major and Teres minor. The upper part of the surface between the ridge and the axillary border is narrow; it gives origin to the Teres minor, and is crossed by a shallow groove for the passage of the scapular circumflex vessels. The lower part of the surface is somewhat triangular, and gives origin to the Teres major. The two parts are separated by an oblique line which runs downwards and backwards from the axillary border; a fibrous septum is attached to this oblique line, and separates the Teres major from the Teres minor. The upper portion of the Latissimus dorsi glides over the Teres major, and frequently derives a few fibres of origin from the inferior angle of the bone.

The *spine* is a triangular plate, which crosses obliquely the medial four-fifths of the upper part of the dorsal surface of the scapula, and separates the supra- from the infraspinatous fossa. It begins at the vertebral border in a smooth, triangular area over which the tendon of insertion of the lower part of the Trapezius glides, and, gradually becoming more elevated, ends in the acromion,

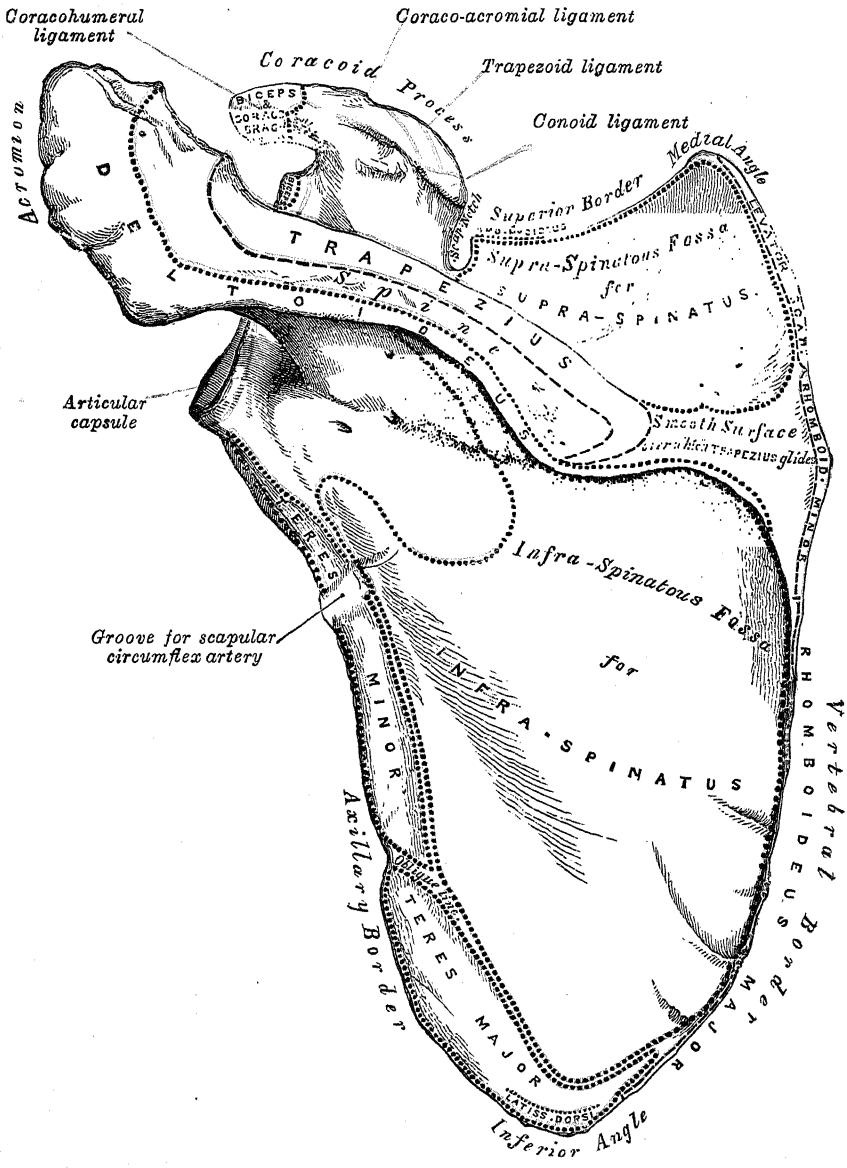
FIG. 370.—The left scapula. Costal aspect.



which overhangs the glenoid cavity. It is flat from above downwards, and its apex is directed towards the vertebral border. It has two surfaces and three borders. Its *superior surface* forms a part of the supraspinatous fossa, and gives origin to a portion of the Supraspinatus. Its *inferior surface* forms part of the infraspinatous fossa, gives origin to a portion of the Infraspinatus, and presents near its centre the orifice of a nutrient canal. The *anterior border* is attached to the dorsal surface of the scapula. The *posterior border*, or *crest of the spine*, is broad, with a superior and an inferior lip, and an intervening rough surface. The Trapezius is attached to the lateral three-fourths of the superior lip, and a rough tubercle is generally seen on the medial portion of

the lip for the tendon of insertion of the lower part of this muscle ; the Deltoideus is attached to the whole length of the inferior lip ; the area between the lips is subcutaneous and partly covered by the tendinous fibres of these muscles. The *lateral border or base of the spine* is thick and slightly concave ; it is continuous above with the under surface of the acromion, below with the posterior

FIG. 371.—The left scapula. Dorsal aspect.



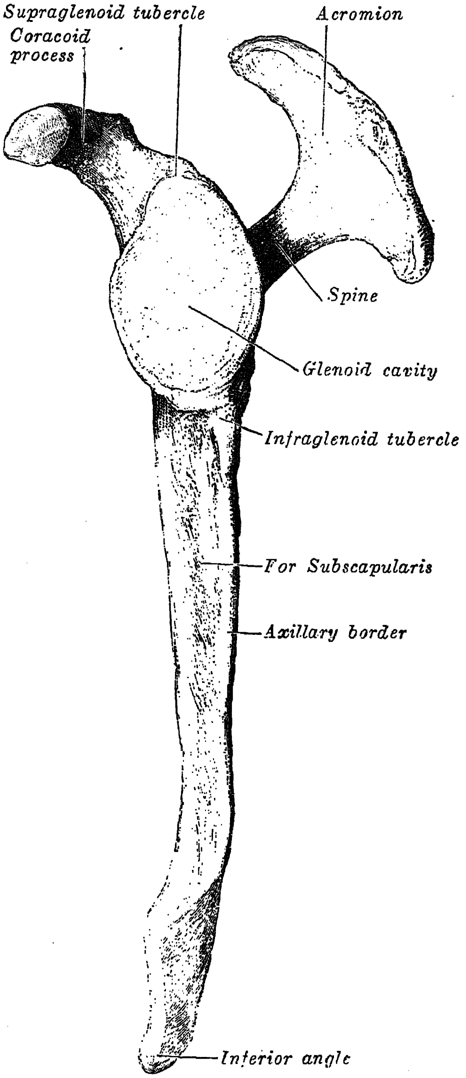
surface of the neck of the scapula. It forms the medial boundary of the *great scapular notch*, which connects the supra- and infraspinatous fossæ.

The *acromion* is a large triangular or oblong process which projects at first lateralwards from the spine, and then curves forwards and upwards, so as to overhang the glenoid cavity. Its *superior surface*, directed upwards, and slightly backwards and lateralwards, is subcutaneous. Its *inferior surface* is smooth and concave. Its *lateral border* is thick and irregular, and on it are three or four tubercles for the tendinous origins of the Deltoideus. Its

medial border, shorter than the lateral, is concave; it gives attachment to a portion of the Trapezius, and presents near its anterior extremity a small, oval surface for articulation with the acromial end of the clavicle. Its *apex*, which corresponds with the point of meeting of the lateral and medial borders in front, is thin, and to it the coraco-acromial ligament is attached.

Of the three *borders* of the scapula, the *superior* is the shortest and thinnest; it is concave, and extends from the medial angle to the base of the coracoid process. At its lateral part is the *scapular notch*, formed partly by the base of the coracoid process. This notch is converted into a foramen by the superior transverse scapular ligament, and transmits the suprascapular nerve; sometimes the ligament is ossified. From the adjacent part of the superior border the Omohyoideus takes origin. The *axillary border* (fig. 372) is the thickest; it begins above at the lower margin of the glenoid cavity, and runs downwards and backwards to the inferior angle. Immediately below the glenoid cavity is the *infraglenoid tuberosity*, a rough impression about 2·5 cm. in length, which gives origin to the long head of the Triceps brachii; in front of this a longitudinal groove extends as far as the lower one-third of this border, and affords origin to part of the Subscapularis. The inferior one-third is thin and serves for the attachment of a few fibres of the Teres major behind, and of the Subscapularis in front. The *vertebral border* is the longest and extends from the medial to the inferior angle; it is bent so that the portion above the spine forms an obtuse angle with the part below. It gives insertion to the Levator scapulæ above the triangular surface at the apex of the spine, to the Rhomboideus minor on the edge of that surface, and to the Rhomboideus major below it; the last muscle is usually attached by means of a fibrous arch, connected above to the lower part of the triangular surface at the apex of the spine, and below to the lower part of the vertebral border.

FIG. 372.—The left scapula. Lateral aspect.

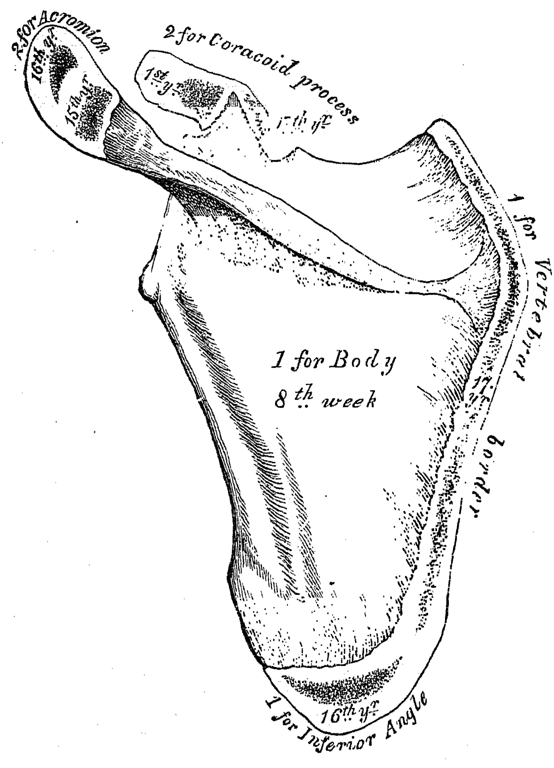


Of the three *angles*, the *medial*, at the junction of the superior and vertebral borders, is thin and smooth; it gives attachment to a few fibres of the Levator scapulæ. The *inferior angle*, thick and rough, is formed by the union of the vertebral and axillary borders; its dorsal surface gives origin to the Teres major and frequently to a few fibres of the Latissimus dorsi. The *lateral*

angle is the thickest part of the bone, and is sometimes called the *head* of the scapula. It supports the coracoid process, and on its lateral surface is a shallow pyriform, articular surface, the *glenoid cavity* (fig. 372). This cavity looks lateralwards and forwards and articulates with the head of the humerus; it is broader below than above and its vertical diameter is the longer. To its margin is attached a fibrocartilaginous lip, the glenoidal labrum, which deepens the cavity. At its apex is a small elevation, the *supraglenoid tuberosity*, from which the long head of the Biceps brachii takes origin.

The *neck* of the scapula (collum scapulæ) is the somewhat constricted part between the body and the head of the bone. Above, it corresponds with the

FIG. 373.—A plan of the ossification of the scapula. From seven centres.



scapular notch, and below, with the upper end of the infraglenoid tuberosity. On the surfaces of the bone its position may be indicated by lines drawn between the points mentioned.

The *coracoid process* is a thick curved process attached by a broad base to the upper part of the head of the scapula; it runs at first upwards and forwards; then, becoming smaller, it changes its direction, and projects forwards and lateralwards. The ascending portion is flat from before backwards; its anterior surface is crossed by the tendon of the Subscapularis, its posterior surface by the tendon of the Supraspinatus. The horizontal portion is flattened from above downwards; its upper surface is convex and irregular, and gives attachment to the Pectoralis minor; its under surface is smooth; its medial and lateral borders are rough, the former giving attachment to the Pectoralis minor, and the latter to the coraco-acromial ligament; the conjoined tendon of origin of the Coracobrachialis and short head of the Biceps brachii, and the coracoclavicular fascia are attached to the apex of the coracoid process. On the angle of junction of the ascending and horizontal portions of the coracoid process is a rough impression for the attachment of the conoid ligament; and running from this impression obliquely forwards and lateralwards, on to the upper surface of the horizontal portion, is an elevated ridge for the attachment of the trapezoid ligament.

Structure.—The head, processes, and thickened parts of the scapula contain spongy substance; the rest consists of a thin layer of compact bone. The central part of the supraspinatous fossa and the greater part of the infraspinatous fossa are thin; occasionally the bone is wanting in these situations, the gaps being filled by fibrous tissue.

Ossification (fig. 373).—The scapula is ossified from seven or more centres: one for the body, two for the coracoid process, two for the acromion, one for the vertebral border, and one for the inferior angle.

The centre for the body appears in the eighth week of fœtal life, and spreads to form an irregular quadrilateral plate of bone, immediately behind the glenoid cavity. This plate forms the chief part of the bone, and the spine grows up from its dorsal surface about the third month. At birth, the glenoid cavity, coracoid process, acromion, vertebral border, and inferior angle are cartilaginous. In the first year of life, ossification begins in the middle of the coracoid process, and this process joins the rest of the bone about the fifteenth year. Between the fourteenth and twentieth years, ossification of the remaining parts usually takes place in the following order; first, in the root of the coracoid process; second, near the base of the acromion; third, in the inferior angle and contiguous part of the vertebral border; fourth, near the extremity of the acromion; fifth, in the vertebral border. The base of the acromion is formed by an extension from the spine; the rest of the acromion is ossified from two centres which unite, and then join the extension from the spine. The upper one-third of the glenoid cavity is ossified from a subcoracoid centre, which appears between the tenth and eleventh, and joins between the sixteenth and the eighteenth, years. Further, an epiphysial plate appears for the lower part of the glenoid cavity, while the tip of the coracoid process frequently presents a separate centre. These various epiphyses are joined to the bone by the twenty-fifth year.

Applied Anatomy.—Fractures of the body of the scapula are rare, owing to the mobility of the bone, the thick layers of muscles by which it is encased, and the elasticity of the ribs on which it rests. The most frequent course of a fracture is from the scapular notch to the infraglenoid tuberosity, and it derives its principal interest from its simulation of a subglenoid dislocation of the humerus. The diagnosis can be made by noting the alteration in the position of the coracoid process. The acromion is more frequently broken than any other part of the bone, and fibrous union is very liable to follow. Failure of bony union between the acromion and spine sometimes occurs and may simulate a fracture; and the junction of these two parts may be then effected by fibrous tissue, or by an imperfect articulation.

The presence of 'winged scapulæ' (scapulæ alatæ) described in thin persons of feeble muscular development in whom the lower angles of the scapulæ project unduly, is due partly to abnormal roundness of the thoracic wall, and partly to weakness and flaccidity of the Latissimus dorsi and Serratus anterior. The shoulders are held low in these subjects, and the clavicles slope downwards and forwards, carrying with them the scapulæ, which fit ill to the posterior wall of the chest and so tend to project from it.

The Clavicle (Clavicula)

The **clavicle** or collar-bone (figs. 374, 375) articulates medially with the manubrium sterni, and laterally with the acromion of the scapula.* It is a long bone, and is placed nearly horizontally at the upper and anterior part of the thorax. It is bent somewhat like the italic letter *f*, presenting a double curvature, with a convexity forwards at the sternal end and a concavity forwards at the acromial end. Its lateral one-third is flattened, whilst its medial two-thirds are cylindrical or prismoid in form.

The **lateral one-third** of the clavicle has two surfaces, an upper and a lower, and two borders, an anterior and a posterior. The *upper surface* is flat and rough; it affords attachment to the Deltoideus in front, and the Trapezius behind; between these a small portion of the surface is subcutaneous. The

* The clavicle acts especially as a fulcrum to enable the muscles to give lateral motion to the arm. It is accordingly absent in those animals whose fore-limbs are used only for progression, but is present for the most part in animals whose anterior extremities are clawed and used for prehension, though in some of them—as, for instance, in a large number of the carnivora—it is a rudimentary bone suspended among the muscles, and not articulating with either the scapula or the sternum.

lower surface is flat; at its posterior border, near the junction with the medial two-thirds of the bone, is a rough eminence, the *coracoid tuberosity* (conoid tubercle); this overlies the coracoid process of the scapula, and gives attachment to the conoid ligament. From this tuberosity, the *oblique or trapezoid ridge* runs forwards and lateralwards, and affords attachment to the trapezoid ligament. The *anterior border* is concave, thin, and rough, and gives origin to a portion of the Deltoideus; at its medial part there is frequently a tubercle, the *deltoid tubercle*. The *posterior border*, convex, rough, and thicker than the anterior, gives insertion to a part of the Trapezius.

The medial two-thirds of the clavicle constitute the prismoid portion of the bone, which is marked by three borders, separating three surfaces. The *anterior border* is continuous with the anterior border of the flat portion. Its lateral part is smooth, and corresponds to the interval between the attachments of the

Fig. 374.—The left clavicle. Superior aspect.

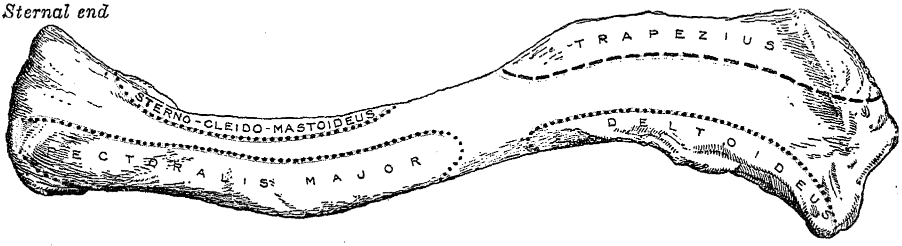
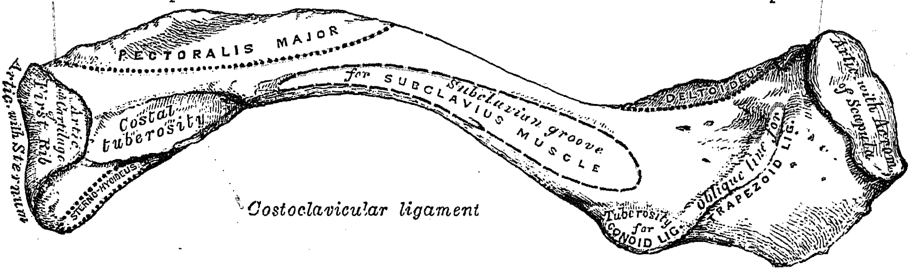


Fig. 375.—The left clavicle. Inferior aspect.



Pectoralis major and Deltoideus; its medial part forms the lower boundary of an elliptical surface for the attachment of the clavicular portion of the Pectoralis major. The *superior border* is continuous with the posterior border of the flat portion, and separates the anterior from the posterior surface. Smooth and rounded laterally, it becomes rough towards the medial one-third for the attachment of the Sternocleidomastoideus, and ends at the upper angle of the sternal extremity. The *subclavian or posterior border* separates the posterior from the inferior surface, and extends from the coracoid tuberosity to the costal tuberosity; it forms the posterior boundary of the groove for the Subclavius, and gives attachment to a layer of cervical fascia which envelops the Omohyoideus. The *anterior surface* is between the superior and anterior borders. Its lateral part looks upwards, and is continuous with the superior surface of the flattened portion; it is smooth, convex, and nearly subcutaneous, being covered only by the Platysma. Its medial part is divided by a narrow subcutaneous region into two areas; a lower, elliptical in form, and directed forwards, for the attachment of the Pectoralis major; and an upper, for the attachment of the clavicular part of the Sternocleidomastoideus. The *posterior or cervical surface* is smooth, and looks backwards towards the root of the neck. It is limited, above, by the superior border; below, by the subclavian border;

medially, by the margin of the sternal extremity ; and laterally, by the coracoid tuberosity. It is in relation with the transverse scapular vessels, and, at the junction of the curves of the bone, with the brachial plexus of nerves and the subclavian vessels. Near the sternal end, this surface gives attachment to part of the Sternohyoideus ; and near the middle of this surface is a foramen for the transmission of a nutrient artery which runs lateralwards into the bone. A second nutrient artery may enter this, or the inferior, surface. The *inferior or subclavian surface* is between the anterior and subclavian borders. It is narrow medially, but increases in width laterally, and is continuous with the lower surface of the lateral one-third. On its medial part is a rough area, the *costal tuberosity* (rhomboid impression), rather more than 2 cm. in length, for the attachment of the costoclavicular ligament. The rest of this surface is grooved, and gives insertion to the Subclavius muscle ; the coracoclavicular fascia splits to enclose the muscle and is attached to the margins of the groove.

The **sternal end** of the clavicle is triangular in form, and is directed medialwards, and a little downwards and forwards. On it is an articular facet which is concave from before backwards, and convex from above downwards ; it articulates with the articular disc of the sternoclavicular joint. This facet is continued on to the anterior and inferior sufaces of the bone as a small semi-oval area for articulation with the cartilage of the first rib. The circumference of the articular surface is rough for the attachment of ligaments ; the upper angle and a narrow rough area below it give attachment to the articular disc.

The **acromial end** of the clavicle presents a small, flattened, oval surface directed slightly downwards, for articulation with the acromion of the scapula. The upper margin of the facet is rough for the attachment of the acromioclavicular ligament.

In the female, the clavicle is shorter,* thinner, less curved, and smoother than in the male. In the female the acromial end is a little below the level of the sternal end; in the male it is on a level with, or slightly higher than, the sternal end. In persons who perform hard manual labour the clavicle is thicker and more curved, and its ridges for muscular attachment are better marked.

Structure.—The clavicle consists of spongy substance, enveloped by a layer of compact bone which is much thicker in the intermediate part than at the ends of the bone.

Ossification.—The clavicle begins to ossify before any other bone in the body, and is ossified from three centres. The body of the bone is ossified from two primary centres,† a medial and a lateral, which appear between the fifth and sixth weeks of fœtal life, and fuse about the forty-fifth day ; a secondary centre for the sternal end appears about the eighteenth or twentieth year, and unites with the body of the bone about the twenty-fifth year.

In a 14 mm. embryo the future clavicle is represented by a band of mesoderm which extends from the acromion of the scapula to the tip of the first rib, and is continuous with the rudiment of the sternum. In this band a medial and a lateral mass of ' precartilage ' is developed, and in the adjacent ends of these masses the two centres for the body of the bone appear and soon fuse with each other. The sternal and acromial ends of the precartilaginous masses are converted into cartilage and into this the ossification of the body of the bone extends.

Applied Anatomy.—The clavicle is very frequently fractured, since it is much exposed to violence, and is the only bony connexion between the upper limb and the trunk, acting as a buttress to keep the point of the shoulder away from the thorax. It is, moreover, slender, and is very superficial. The most common cause is indirect violence, as the result of force applied to the hand or shoulder, and the bone then gives way at the junction of its lateral with its intermediate third, that is to say, at the junction of the two curves, for this is its weakest part. The fracture is generally oblique, and the displacement of the lateral fragment is downwards, forwards, and medialwards. The deformity is mainly due to the weight of the arm acting upon the fragment when the buttress-like action of the bone is gone, assisted by the muscles which pass from the thorax to the upper extremity.

* F. G. Parsons (*Journal of Anatomy and Physiology*, vol. li.) gives the following as the average lengths of the clavicle in the male and female : male, left, 154 mm., right, 152 mm. ; female, left, 139 mm., right, 138 mm.

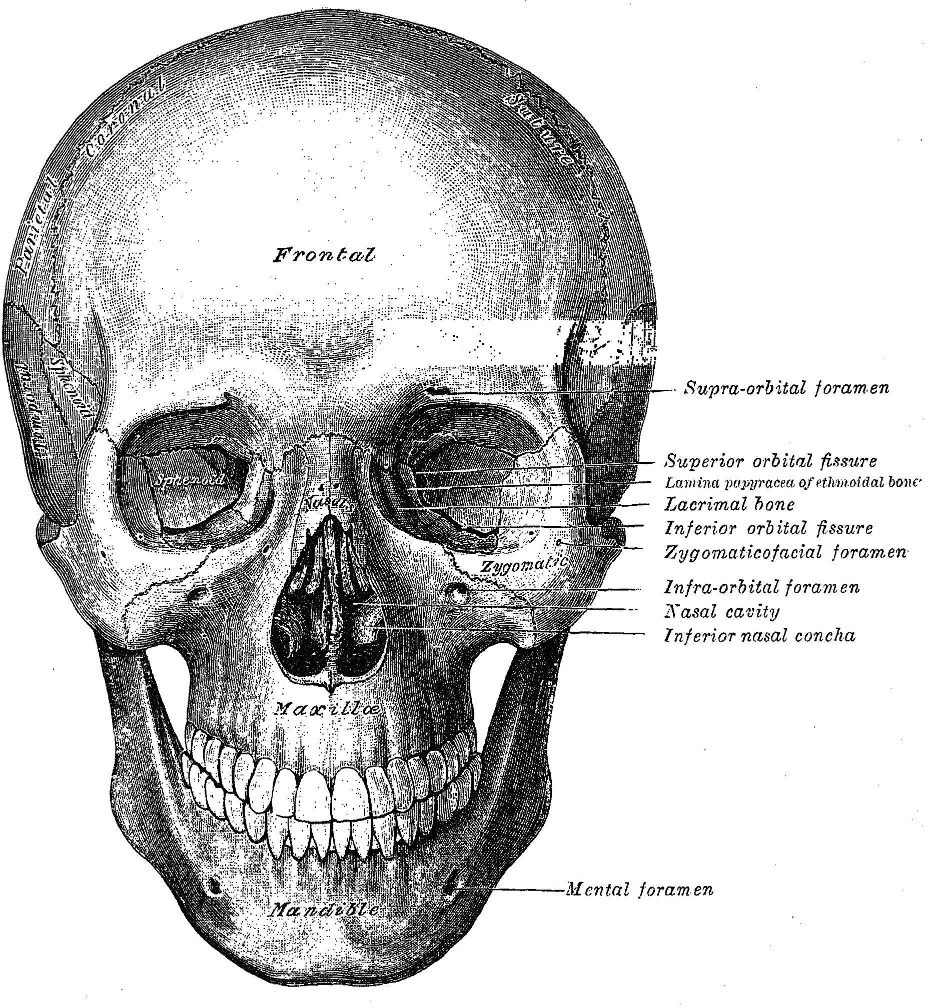
† Mall, *American Journal of Anatomy*, vol. v., 1906 ; Fawcett, *Journal of Anatomy and Physiology*, vol. xlvii. ; Hanson, *Anatomical Record*, vol. xix. (number 6), 1920.

divided by the medial nuchal line which runs downwards and forwards from the inion to the foramen magnum; this line gives attachment to the ligamentum nuchæ. The muscles attached to the planum nuchale are enumerated on p. 196. Below and in front are the mastoid processes, convex laterally and grooved medially by the mastoid notches. In or near the occipitomastoid suture is the mastoid foramen for the passage of the mastoid emissary vein.

Norma Frontalis (fig. 356)

When viewed from the front, the skull exhibits a somewhat oval outline, limited above by the frontal bone, below by the body of the mandible, and laterally by the zygomatic bones and the mandibular rami. The upper part,

Fig. 356.—The skull. Anterior aspect. (Norma frontalis.)



formed by the frontal squama, is smooth and convex. The lower part, made up of the bones of the face, is irregular; it is excavated laterally by the orbital cavities, and presents in the middle the anterior nasal aperture leading to the nasal cavities, and below this the transverse slit between the upper and lower dental arcades. The frontal tuberosities stand out more or less prominently, and beneath these are the superciliary arches, the medial ends of which are

Between the tubercles is the *intertubercular sulcus* (bicipital groove), which lodges the long tendon of the Biceps brachii, transmits a branch of the anterior humeral circumflex artery to the shoulder-joint, and gives insertion to the tendon of the Latissimus dorsi. The sulcus diminishes in depth distalwards, and, near the junction of the upper with the middle one-third of the bone, is continuous with the anteromedial surface. The lips of the sulcus are called the *crests of the greater and lesser tubercles* (bicipital ridges), and form the upper parts of the anterior and medial borders of the body of the bone.

The body or shaft of the humerus is almost cylindrical above, but prismoid and flattened below; it has three borders and three surfaces.

The *anterior border* runs from the front of the greater tubercle above to the coronoid fossa below, and separates the anteromedial from the anterolateral surface. Its upper part, the crest of the greater tubercle, serves for the insertion of the tendon of the Pectoralis major; its middle part forms the anterior boundary of the deltoid tuberosity; its lower part is smooth and rounded, and affords attachment to the Brachialis.

The *lateral border* runs from the back of the greater tubercle to the lateral epicondyle, and separates the anterolateral from the posterior surface. Its upper half, which is indistinctly marked, gives insertion to the lower part of the Teres minor, and origin to the lateral head of the Triceps brachii; its middle part is traversed by a shallow oblique depression, the *sulcus nervi radialis* (musculospiral groove). Its lower part forms a prominent rough margin, the *lateral supracondylar ridge*, which is curved forwards, and gives attachment to the lateral intermuscular septum. The proximal two-thirds of this ridge give origin to the Brachioradialis; the

FIG. 377.—The left humerus. Anterior aspect.

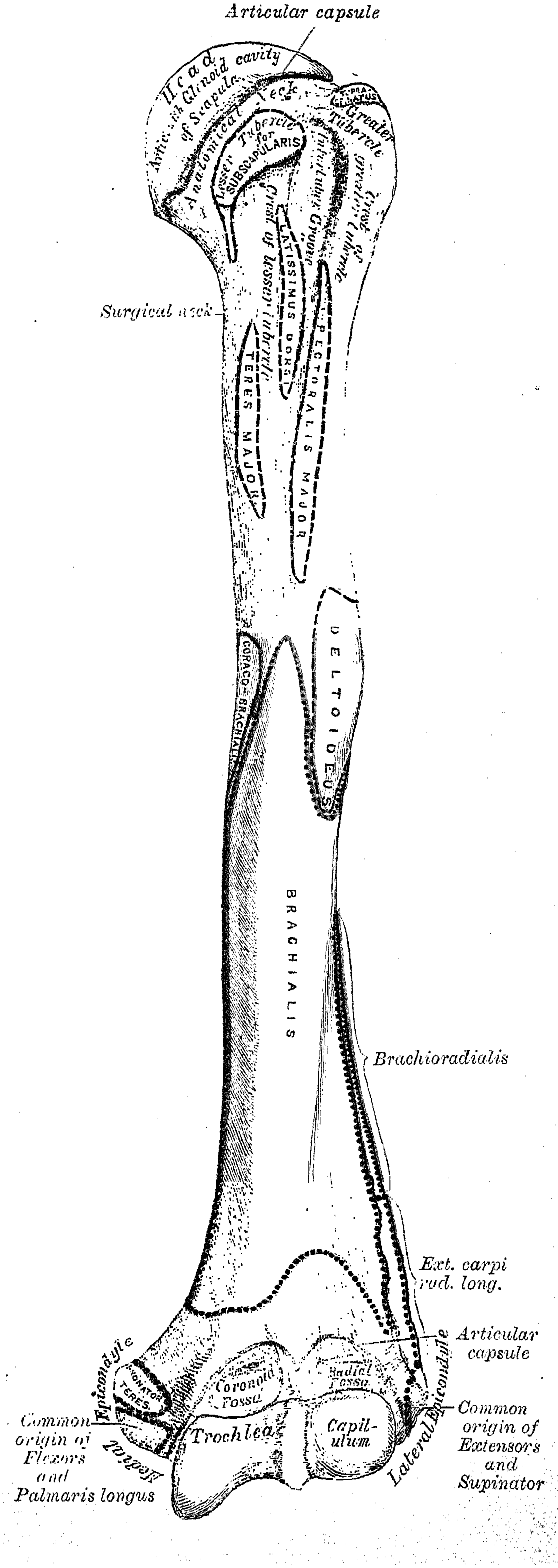
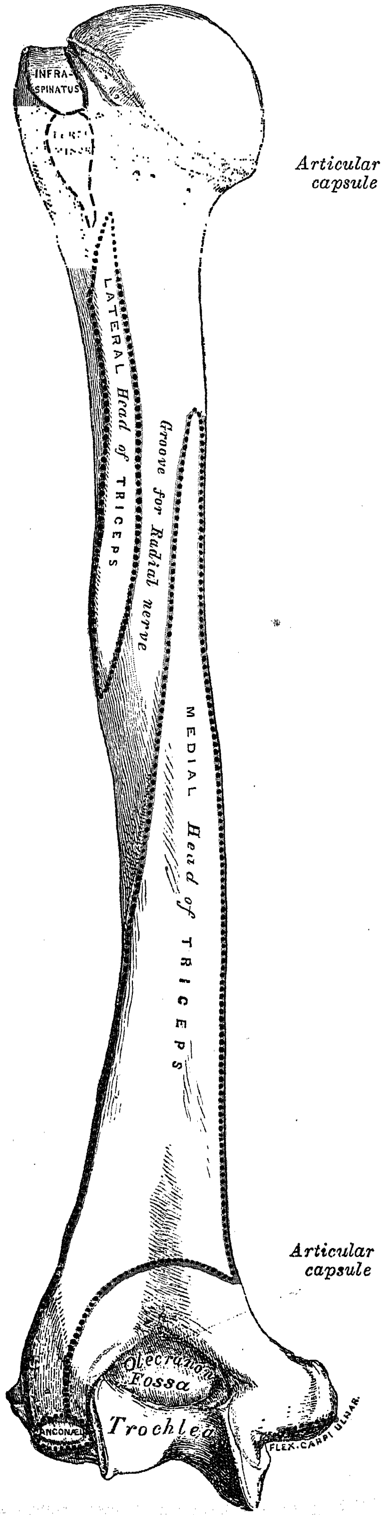


FIG. 378.—The left humerus. Posterior aspect.



distal one-third, to the Extensor carpi radialis longus.

The *medial border* extends from the lesser tubercle to the medial epicondyle and separates the anteromedial from the posterior surface. Its upper part, the crest of the lesser tubercle, gives insertion to the tendon of the Teres major. Near the middle is a slight impression for the insertion of the Coracobrachialis, and just below this the nutrient canal enters the bone, and is directed downwards; sometimes there is a second nutrient canal at the commencement of the radial sulcus. The inferior one-third of this border forms the *medial supracondylar ridge* which gives attachment to the medial intermuscular septum, and is prominent below.

The *anterolateral surface* is directed lateralwards above, where it is smooth, rounded, and covered by the Deltoideus; forwards and lateralwards below, where it is slightly concave from above downwards, and gives origin to part of the Brachialis. About the middle of this surface is a rough elevation, triangular in shape with the apex below, the *deltoid tuberosity*, for the insertion of the Deltoideus; below this is the sulcus nervi radialis, which is directed from behind, forwards, and distalwards, and transmits the radial nerve and arteria profunda brachii.

The *anteromedial surface*, less extensive than the anterolateral, is directed forwards above, forwards and medialwards below; its upper part, which is narrow, forms the floor of the intertubercular sulcus and gives insertion to the tendon of the Latissimus dorsi; its middle part is slightly rough for the attachment of some of the fibres of the tendon of insertion of the Coracobrachialis; its lower part is smooth, concave from above downwards, and gives origin to the Brachialis.*

* A hook-shaped process of bone, the *supracondylar process*, varying from 2 mm. to 20 mm. in length, is not infrequently found projecting from the anteromedial surface of the body of the humerus, about 5 cm. above the medial epicondyle. It is curved downwards and forwards, and its pointed end is connected to the medial border, just above the epicondyle, by a fibrous band which gives origin to a portion of the Pronator teres; through the arch completed by this fibrous band the median nerve and brachial artery pass, when these structures deviate from their usual course. Sometimes the nerve alone is transmitted through it, or the nerve may be accompanied by the ulnar artery, in cases of high division of the brachial artery. A groove is usually found behind the process, in which the nerve and artery are lodged. This arch is the homologue of the supracondyiar foramen found in many animals, and probably serves in them to protect the nerve and artery from compression during the contraction of the muscles in this region.

The *posterior surface* appears somewhat twisted, so that its upper part is directed a little medialwards, its lower part backwards. Nearly the whole of this surface is covered by the lateral and medial heads of the Triceps brachii, the former arising above, the latter below the radial sulcus.

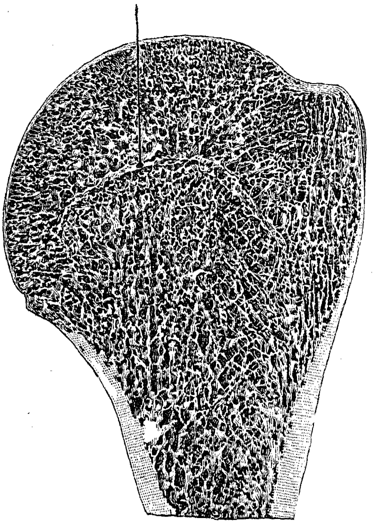
The **lower end** of the humerus is flattened from before backwards, and curved slightly forwards; it ends in a broad, articular surface which is divided into two parts by a smooth ridge. Projecting on either side, at a higher level than the articular surface, are the lateral and medial epicondyles. The *articular surface* (fig. 379) is curved slightly forwards, and its medial extremity is lower than the lateral. The lateral portion of this surface is a smooth, rounded eminence, named the *capitulum* of the humerus; it articulates with the cup-shaped depression on the head of the radius, and is limited to the front and lower part of the bone. On the medial side of the capitulum is a shallow groove, in which the medial margin of the head of the radius is received; above the front part of the capitulum is a small depression, the *radial fossa*, which receives the anterior border of the head of the radius, when the forearm is flexed. The medial portion of the articular surface is named the *trochlea* or pulley; it articulates with the semilunar notch of the ulna. Its central part consists of

Fig. 379.—The lower end of the left humerus. Inferior aspect.

a deep groove which winds spirally from before backwards and lateralwards round the lower end of the bone; the groove is deeper behind where it expands to occupy the whole width of the trochlea. The medial margin of the trochlea is prominent, and forms about two-thirds of a circle, and the adjacent portion of the articular surface is convex from side to side on the front and lower part of the bone; on the posterior surface the convexity disappears. The lateral margin of the trochlea is rounded in front and below, where it is separated from the capitulum by the groove which receives the margin of the head of the radius; posteriorly the margin is sharp and prominent. Above the trochlea, in front, is a depression, the *coronoid fossa*, which receives the coronoid process of the ulna when the forearm is flexed, and above the trochlea, behind, is a deep triangular depression, the *olecranon fossa*, in which the summit of the olecranon is received when the forearm is extended. These fossæ are separated from one another by a thin lamina of bone, which is sometimes perforated by the *supratrochlear foramen*; they are lined in the recent state by the synovial stratum, and their margins afford attachment to the fibrous stratum, of the articular capsule of the elbow-joint. The *lateral epicondyle* is small and tuberculated, and curved a little forwards; it gives attachment to the radial collateral ligament of the elbow-joint and to a tendon common to the origin of the Supinator and some of the extensor muscles of the forearm. The *medial epicondyle*, larger and more prominent than the lateral, is directed a little backwards; it gives attachment to the ulnar collateral ligament of the elbow-joint, to the Pronator teres, and to a common tendon of origin of some of the flexor muscles of the forearm; the ulnar nerve and posterior ulnar recurrent artery run in a groove (*sulcus nervi ulnaris*) on the back of this epicondyle. The supracondylar ridges end at the epicondyles.

Structure.—The ends of the humerus consist of spongy substance, covered with a thin layer of compact bone (fig. 380); the body is composed of a cylinder of compact bone, thicker at the centre than towards the extremities, and a large medullary canal extends throughout its length.

Fig. 380.—A longitudinal section through the head of the left humerus.



Ossification (figs. 381, 382).—The humerus is ossified from eight centres, one for each of the following parts: the body, the head, the greater tubercle, the lesser tubercle, the capitulum and lateral part of the trochlea, the medial part of the trochlea, and one for either epicondyle. The centre for the body appears near the middle in the eighth week of fœtal life, and gradually extends towards the ends, which at birth are cartilaginous. During the first year, occasionally before birth, ossification begins in the head, during the third year in the greater tubercle, and during the fifth in the lesser tubercle. By the sixth year the centres for the head and tubercles have joined to form a single large epiphysis, which fuses with the body of the humerus about the twentieth year. The lower end is ossified as follows. At the end of the second year ossification begins in the capitulum and extends medialwards to form the chief part of the articular surface; the centre for the medial part of the trochlea appears about the twelfth year. Ossification begins in the medial epicondyle about the fifth year, and in the lateral about the thirteenth or fourteenth year. The centre for the lateral epicondyle fuses with those for the trochlea and capitulum, and the epiphysis thus formed unites with the body about the sixteenth or seventeenth year; the medial epicondyle unites with the body about the eighteenth year.

Applied Anatomy.—The upper end of the humerus, though the first to ossify, is the last to join the body, and the length of the bone is mainly due to growth from the upper epiphysial plate. Hence, in cases of amputation through the arm in young subjects, the humerus continues to grow considerably, and the lower end of the bone, which immediately after the operation was covered with a thick cushion of soft tissue, begins to project, thinning the soft parts and rendering the stump conical. This may necessitate the removal of about 5 cm. of the bone, and even after this operation a recurrence of the conical stump may take place. The region of the upper epiphysis is a common site for the growth of tumours, both innocent and malignant.

The upper one-third of the humerus is best exposed through an incision along the anterior border of the Deltoideus; the middle one-third by continuing this incision downwards through the middle of the Brachialis between the parts of the muscle supplied by the musculocutaneous and radial nerves; the lower one-third by an incision along the lateral epicondylar ridge.

Fractures of the humerus are common. This bone is probably more frequently fractured by muscular action than any other long bone; it is usually the body of the bone, just below the insertion of the Deltoideus, which is thus broken, and the accident has been known to happen from throwing a stone or a hand-grenade. Fracture of the anatomical neck is a very rare accident. Fracture of the surgical neck of the bone is not uncommon; impaction may occur, or the upper end of the lower fragment may be displaced into the axilla and damage the vessels or nerves. The fracture simulates dislocation of the shoulder-joint, but can be distinguished by the fact that the head of the bone remains in its normal position and the greater tubercle still forms the most prominent point of the shoulder. Separation of the upper epiphysis sometimes occurs in the young subject, and is marked by a characteristic deformity, the upper end of the diaphysis projecting abruptly at the front of the joint a short distance below the coracoid process. In fractures of the upper end of the humerus, extension with the arm in the abducted position is necessary, so that should ankylosis take place the mobility of the scapula may be brought into full use. In fractures of the body of the humerus the lesion may take place at any point, but appears to be more common in the lower than the upper part of the bone. The points of interest in connexion with these fractures are: (1) that the radial nerve may be injured as it lies in the groove on the bone, or may become involved in the callus which is

subsequently thrown out; and (2) the frequency of non-union, which is believed to be more common in the humerus than in any other bone. The non-union is in some measure due to the difficulty in fixing the bone, since the upper end articulates with the movable scapula, and the body lies by the chest-wall which moves with each respiration. Again, muscle is attached to the entire circumference of the bone and is liable to get between the fragments, should there be any overlapping of the latter. The axillary (circumflex) nerve

Fig. 381.—A plan of the ossification of the humerus.

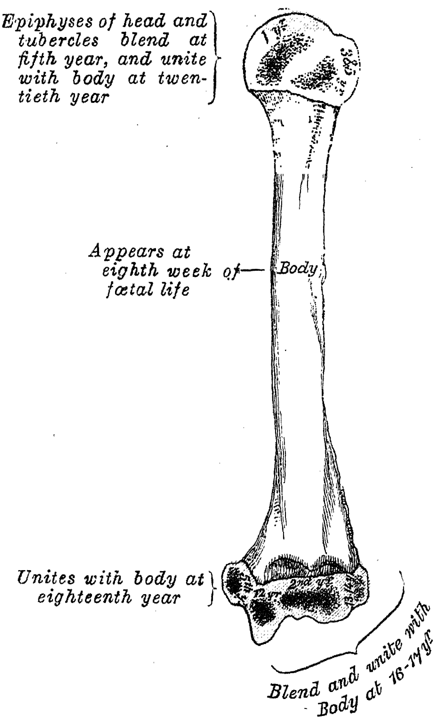
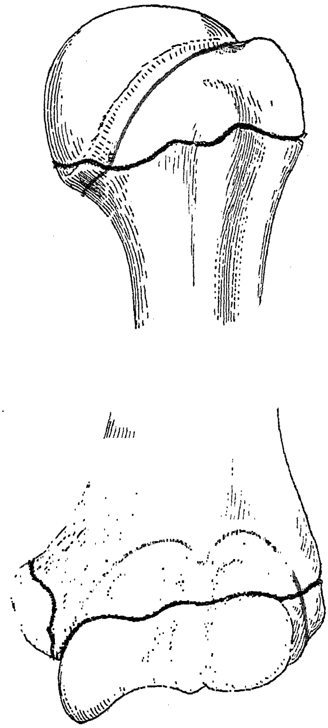


Fig. 382.—The epiphysial lines of the left humerus in a young adult. Anterior aspect.



The lines of attachment of the articular capsules are in blue.

may be injured by fractures of the upper end of the bone and the ulnar nerve by fracture of the medial epicondyle. In fractures of the lower end it is important to distinguish between those that involve the elbow-joint and those that do not; the former are always serious, as they may lead to impairment of the utility of the limb; they include the T-shaped fracture and oblique fractures which involve the articular surface. Those which do not involve the joint are the transverse fracture above the epicondyles, and the so-called epitrochlear fracture, where the tip of the medial epicondyle is broken off, generally by direct violence.

The Radius

The **radius** (figs. 383 and 384) is situated on the lateral side of the forearm. It is a long bone, prismoid in form and slightly curved longitudinally. Its upper end is small, and forms only a small part of the elbow-joint; its lower end is large, and forms a large part of the wrist-joint.

The **upper end** of the radius consists of a head, neck, and tuberosity. The *head* is disc-shaped, and on its proximal surface is a shallow cup for articulation with the capitulum of the humerus. The circumference of the head is smooth; it is broad medially where it articulates with the radial notch of the ulna, and narrow in the rest of its extent which is embraced by the annular ligament. The head is supported on a round, smooth, and constricted *neck*. Below the

Fig. 383.—The bones of the left forearm. Volar aspect.

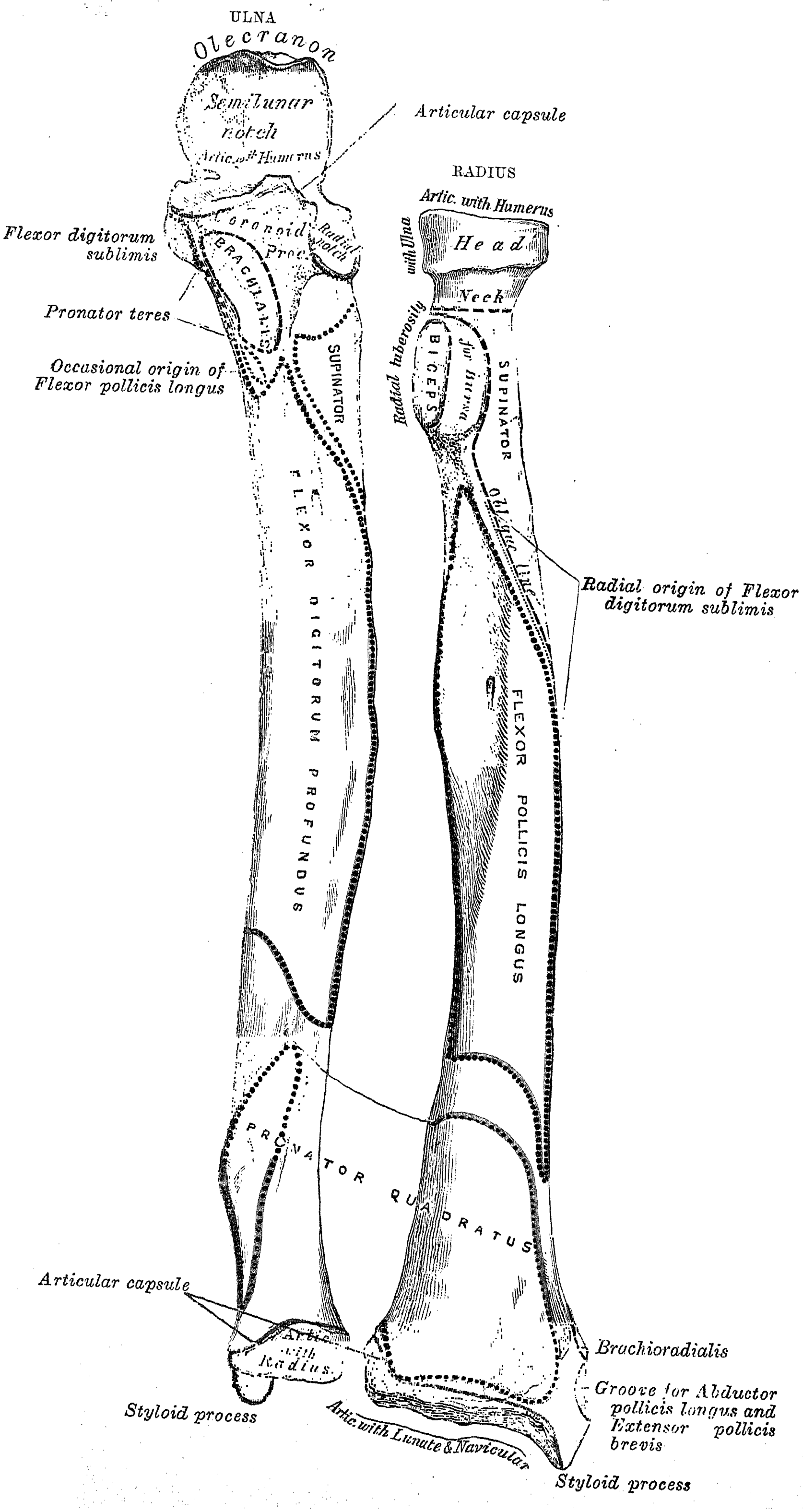
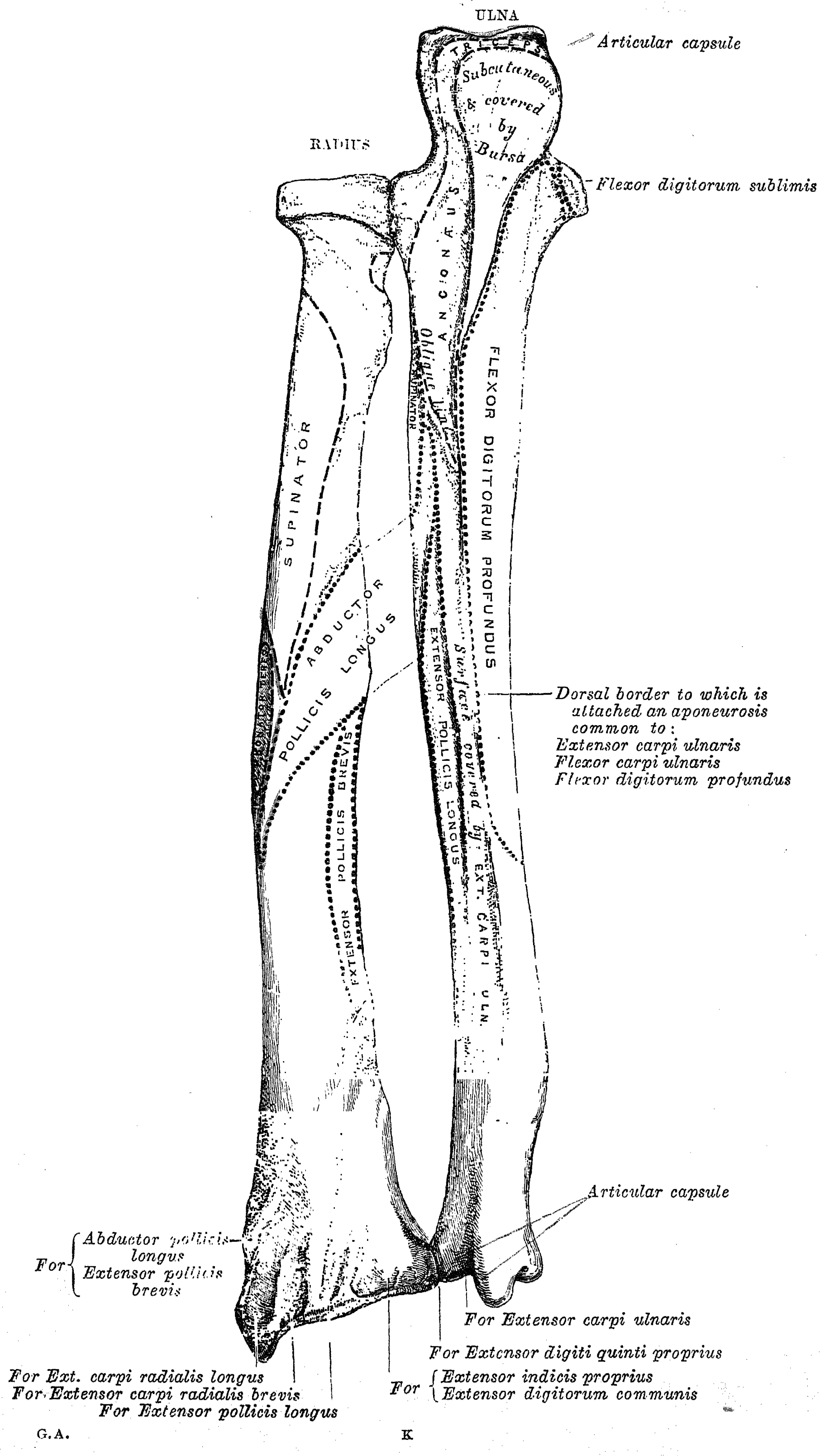


FIG. 384.—The bones of the left forearm. Dorsal aspect.



medial part of the neck is an eminence, the *radial tuberosity*, the surface of which is divided into a dorsal rough portion for the insertion of the tendon of the Biceps brachii, and a volar smooth portion on which a bursa is interposed between the tendon and the bone.

The **body** or **shaft** of the radius is prismoid in form, narrower above than below, and slightly curved, so as to be convex laterally. It has three borders and three surfaces.

The *volar or anterior border* separates the volar from the lateral surface, and extends from the lower part of the tuberosity above, to the anterior part of the base of the styloid process below. Its upper part is prominent, and from its oblique direction has been named the *oblique line*; it gives origin to the Flexor digitorum sublimis and Flexor pollicis longus; the surface above the line gives insertion to part of the Supinator. The middle part of the volar border is indistinct. The lower part is prominent, and gives insertion to the Pronator quadratus, and attachment to the dorsal carpal ligament; it ends in a small tubercle, into which the tendon of the Brachioradialis is inserted.

The *dorsal or posterior border* separates the dorsal from the lateral surface; it is well-marked only in the middle one-third of the bone.

The *interosseous crest* or *medial border* separates the volar from the dorsal surface, and gives attachment to the antibrachial interosseous membrane (fig. 388); it begins above, at the posterior part of the tuberosity, and its upper part is indistinct. It becomes sharp and prominent as it descends, and divides below into two ridges which are continued to the volar and dorsal margins of the ulnar notch; to the dorsal ridge the lower part of the antibrachial interosseous membrane is attached, and on the triangular surface between the ridges a part of the Pronator quadratus is inserted.

The *volar or anterior surface* is concave in its upper three-fourths, and gives origin to the Flexor pollicis longus; its lower one-fourth is broad and flat, and affords insertion to the Pronator quadratus. A prominent ridge limits the insertion of the Pronator quadratus below, and between this ridge and the carpal articular surface is a triangular rough surface for the attachment of the volar radiocarpal ligament. At the junction of the upper with the middle one-third of the volar surface is the nutrient canal, directed obliquely upwards.

The *dorsal surface* is convex and smooth in the upper one-third of its extent, and covered by the Supinator. Its middle one-third, broad and slightly concave, gives origin to the Abductor pollicis longus above, and the Extensor pollicis brevis below. Its lower one-third, broad and convex, is covered by the tendons of the muscles which subsequently run in the grooves on the lower end of the bone.

The *lateral surface* is convex; its upper part gives insertion to the Supinator; near its centre is a rough ridge, for the insertion of the Pronator teres; in contact with its lower part are the tendon of the Brachioradialis and the tendons of the Extensores carpi radialis longus et brevis.

The **lower end** of the radius is large and is provided with two articular surfaces—one below, for the carpus, and another at the medial side, for the ulna. The carpal articular surface (fig. 389) is triangular, concave, smooth, and divided by a slightly-marked anteroposterior ridge into two parts. The lateral, triangular part, articulates with the navicular bone; the medial, quadrilateral part, with the lunate bone. The ulnar articular surface is called the *ulnar notch* (sigmoid cavity); it is narrow and concave, and articulates with the head of the ulna. These two articular surfaces are separated by a prominent ridge, to which the base of the triangular articular disc is attached; this disc separates the radiocarpal joint from the distal radio-ulnar joint. The lower end of the bone has three non-articular surfaces—volar, dorsal, and lateral. The *volar surface*, rough and irregular, affords attachment to the volar radiocarpal ligament. The *dorsal surface* is convex; it affords attachment to the dorsal radiocarpal ligament, and is marked by three grooves. Enumerated from the lateral side, the first groove is broad, but shallow, and subdivided by a faint vertical ridge; the lateral part transmits the tendon of the Extensor carpi radialis longus, the medial, the tendon of the Extensor carpi radialis brevis. The second groove, deep and narrow, is bounded laterally by a sharp ridge; it runs obliquely downwards and lateralwards, and transmits the tendon of the Extensor pollicis longus. The third groove is broad, for the passage of the

tendons of the Extensor indicis proprius and Extensor digitorum communis. The lateral part of the lower end of the radius is prolonged downwards as a strong, conical projection, the *styloid process*, the base of which gives attachment to the tendon of the Brachioradialis, the apex to the radial collateral ligament of the wrist-joint. On the lateral surface of the styloid process there is a shallow groove, directed downwards and forwards, and separated from the volar surface by a sharp border; the tendon of the Abductor pollicis longus lies in the anterior part, and the tendon of the Extensor pollicis longus in the posterior part, of this groove.

Fig. 385.—A plan of the ossification of the radius. From three centres.

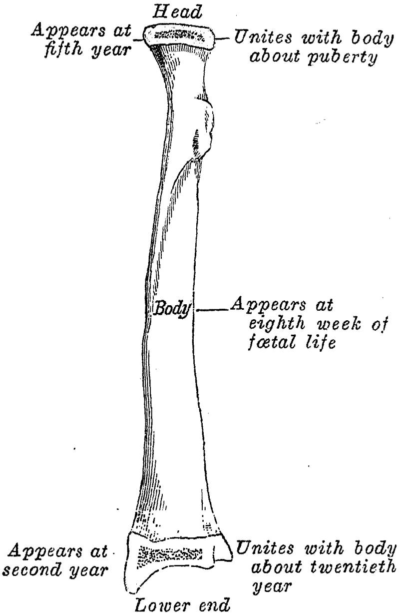
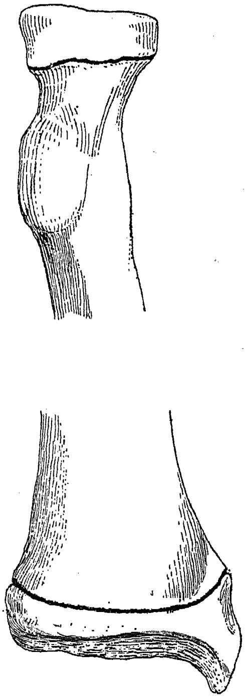


Fig. 386.—The epiphysial lines of the left radius in a young adult. Volar aspect.



The line of attachment of the articular capsule of the wrist-joint is in blue.

Structure.—The structure of the radius is like that of the other long bones.

Ossification (figs. 385, 386).—The radius is ossified from three centres: one for the body, and one for either end. That for the body appears near the middle, in the eighth week of fœtal life. About the close of the second year, ossification begins in the lower end; and at the fifth year, in the upper end. The upper epiphysis fuses with the body at the age of seventeen or eighteen years, the lower about the age of twenty. An additional centre sometimes appears in the radial tuberosity about the fourteenth or fifteenth year.

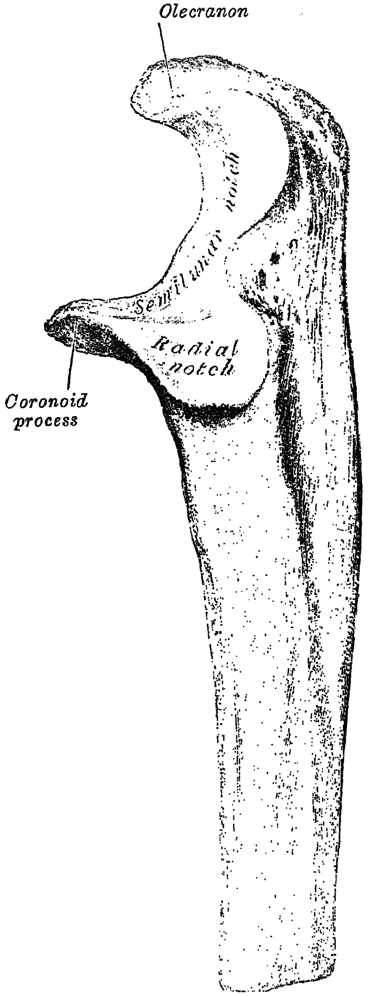
The Ulna

The **ulna** (figs. 383 and 384) is placed at the medial side of the forearm, parallel with the radius. The upper end is thick and strong, and forms a large part of the elbow-joint; the body or shaft diminishes in size from above downwards; the lower end is small, and is excluded from the wrist-joint by the interposition of a triangular articular disc.

On the **upper end** of the ulna (fig. 387) are two curved processes, the olecranon and the coronoid process; and two concave articular cavities, the semilunar and radial notches.

The *olecranon* is a thick, curved eminence, on the upper and dorsal part of the ulna. It is bent forwards at the summit so as to present a prominent beak which is received into the olecranon fossa of the humerus when the forearm is extended. Its *base* is contracted where it joins the body, and is the narrowest part of the upper end of the ulna. Its *dorsal surface*, directed backwards, is triangular, smooth, subcutaneous, and is covered by a bursa. Its *superior surface*, of quadrilateral form, is marked behind by a rough impression for the insertion of the Triceps brachii, and in front, close to the margin, by a slight groove for the attachment of part of the articular capsule of the elbow-joint; between the groove for the articular capsule and the impression for the Triceps brachii is a smooth area which is separated from the tendon of the Triceps brachii by a bursa. Its *volar surface* forms the upper part of the semilunar notch. On its *borders* are grooves continuous with that on the anterior part of the superior surface; that on the medial border gives attachment to the posterior part of the ulnar collateral ligament; that on the lateral border to part of the articular capsule of the elbow-joint. From the medial border a part of the Flexor carpi ulnaris arises; to the lateral border the Anconæus is attached.

FIG. 387.—The upper part of the left ulna. Lateral aspect.



The *coronoid process* is a pyramidal eminence projecting forwards from the front of the upper end of the ulna. Its *base* is continuous with the body of the bone, and is of considerable strength. Its *apex*, pointed and curved slightly upwards, is received into the coronoid fossa of the humerus when the forearm is flexed. Its *upper surface* forms the lower part of the semilunar notch. Its *antero-inferior surface* is concave, and marked by a rough impression for the insertion of the Brachialis; this impression extends on to the upper part of the body of the ulna. At the junction of this surface with the front of the body is a rough eminence, the *ulnar tuberosity*, which gives insertion to a part of the Brachialis; to the lateral border of this tuberosity the oblique cord is attached. On the *lateral surface* of the coronoid process is a narrow, oblong, articular depression, the *radial notch*. The *medial surface* of the process ends superiorly in a prominent, free margin which gives attachment to part of the ulnar collateral ligament. At the front part of this surface is a round eminence for the origin of a small part of the Flexor digitorum sublimis; behind the eminence is a depression for part of the origin of the Flexor digitorum profundus; descending from the eminence is a ridge which gives origin to the ulnar head of the Pronator teres. Frequently a fasciculus of the Flexor pollicis longus arises by a tendinous slip from the lower part of the coronoid process.

The *semilunar notch* (greater sigmoid cavity) (fig. 387), for articulation with the trochlea of the humerus, is a large depression, formed by the olecranon and

the coronoid process. It is concave from above downwards and its deepest part is constricted and sometimes crossed by a groove; it is divided into a medial and a lateral portion by a smooth ridge running from the beak of the olecranon to the apex of the coronoid process. The medial portion is the larger, and is slightly concave transversely; the lateral is convex above, slightly concave below.

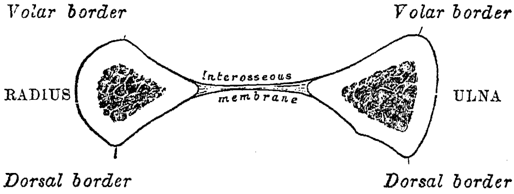
The *radial notch* (lesser sigmoid cavity) (fig. 387) is an oblong, articular depression on the lateral side of the coronoid process, for the reception of the circumferential articular surface of the head of the radius. It is concave from before backwards, and its volar and dorsal margins serve for the attachment of the annular ligament.

The **body** or **shaft** of the ulna, at its upper part, is prismoid in form, and curved, with its convexity directed dorsalwards and lateralwards; its central part is prismoid and straight; its lower part is rounded and bent a little lateralwards The body tapers gradually from above downwards, and has three borders and three surfaces.

The *volar or anterior border* separates the volar from the medial surface; it begins above at the prominent medial angle of the coronoid process, and ends below in front of the styloid process. Its upper part, well defined and its middle portion, smooth and rounded, give origin to the Flexor digitorum profundus; its lower part forms a prominent ridge for the origin of the Pronator quadratus.

The *dorsal border* is subcutaneous, and separates the medial from the dorsal surface; it begins above at the apex of the triangular area on the dorsum of the olecranon, runs at first downwards and lateralwards, and ends below at the back of the styloid process. Its upper three-fourths are well marked and give attachment to an aponeurosis which affords a common origin to the Flexor carpi ulnaris, the Extensor carpi ulnaris, and the Flexor digitorum profundus; its lower one-fourth is smooth and rounded.

Fig. 388.—A transverse section through the left radius and ulna, showing the attachment of the antibrachial interosseous membrane. Superior aspect.



The *interosseous crest* or *lateral border* separates the volar from the dorsal surface and gives attachment to the antibrachial interosseous membrane (fig. 388); it begins above by the union of two lines, which converge from the ends of the radial notch and form the sides of a triangular area for the origin of part of the Supinator. The crest ends below at the head of the ulna; its upper part is sharp and prominent, its lower, smooth and rounded.

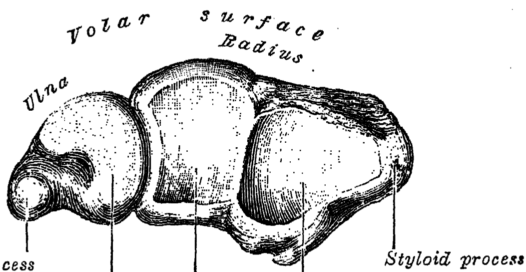
The *volar surface* is broader above than below; its upper three-fourths are concave and give origin to the Flexor digitorum profundus; its lower one-fourth is covered by the Pronator quadratus and is separated from the rest of the surface by a ridge which is directed obliquely downwards and medialwards, and marks the extent of origin of the Pronator quadratus. At the junction of the upper with the middle one-third of the volar surface is the nutrient canal, directed obliquely upwards.

The *dorsal surface*, directed dorsalwards and lateralwards, is broad above; convex and somewhat narrower in the middle; narrow and rounded below. On its upper part is an oblique ridge which runs downwards from the dorsal end of the radial notch to the dorsal border; the upper part of the ridge affords attachment to the Supinator, and the triangular surface above the ridge gives insertion to the Anconæus. Below this ridge the dorsal surface is subdivided by a *perpendicular line*, into a medial and a lateral portion: the medial part is smooth, and covered by the Extensor carpi ulnaris; the lateral part gives origin from above downwards to the Abductor pollicis longus, the Extensor pollicis longus, and the Extensor indicis proprius.

The *medial surface* is broad and concave above, narrow and convex below. Its upper three-fourths give origin to the Flexor digitorum profundus; its lower one-fourth is subcutaneous.

The **lower end** of the ulna is small, and has two eminences; the lateral and larger is termed the head of the ulna; the medial, narrower and more projecting, the styloid process. On the *head* is an articular surface; the distal part of this surface, of a semilunar form (fig. 389), is directed downwards, and comes into contact with the upper surface of the triangular articular disc which separates the ulna from the radiocarpal joint; the remaining portion, directed lateralwards, is narrow and convex, and is received into the ulnar notch of the radius. The *styloid process* projects from the medial and dorsal part of the bone; it descends a little lower than the head, and its rounded apex affords attachment to the ulnar collateral ligament of

FIG. 389.—The lower ends of the left radius and ulna. Inferior aspect.



the wrist-joint. The head is separated from the styloid process, below by a depression for the attachment of the apex of the triangular articular disc, and behind by a groove for the tendon of the Extensor carpi ulnaris.

Structure.—The structure of the ulna is similar to that of the other long bones.

Ossification (figs. 390, 391).—The ulna is ossified from three centres: one each for the body, the lower end, and the top of the olecranon. Ossification begins near the middle of the body, about the eighth week of fœtal life, and soon extends through its greater part. About the fourth year, the centre for the lower end appears in the middle of the head, and extends into the styloid process. About the tenth year, a centre appears in the olecranon and forms a thin scale for the top of this process, the chief part of the process being formed by an upward extension of the body; sometimes the upper part of the olecranon is ossified from two centres. The upper epiphysis joins the body about the sixteenth, the lower about the twentieth year.

Applied Anatomy.—When indirect force is applied to the forearm the radius as a rule gives way, though both bones may suffer. Fractures from indirect force generally take place somewhere about the middle of the bones, while those from direct violence may occur at any part, but are most frequent in the lower half of the bones. The fractures are usually transverse, but may be more or less oblique. A point of interest in connexion with these fractures is the tendency for the two bones to unite across the interosseous membrane; the limb should therefore be put up in a position midway between supination and pronation, which is not only the most comfortable position, but also separates the bones most widely from each other. Anterior and posterior splints are applied in these cases, and should be rather wider than the limb, so as to prevent any side pressure on the bones.

The special fractures of the ulna are: (1) Fracture of the olecranon, which is usually caused by direct violence, by falls on the elbow with the forearm flexed, but occasionally by muscular action in sudden contraction of the Triceps brachii; the most common site of this fracture is at the constricted portion where the olecranon joins the body of the bone, and the fracture is usually transverse; but any part may be broken, and even a thin shell may be torn off. Fractures from direct violence are occasionally comminuted. If the fibrous structures around the process are not torn, the displacement is slight, otherwise the olecranon may be drawn up for a very considerable distance. (2) Fracture of the coronoid process may occur as a complication of dislocation backwards of the bones of the forearm, but it is doubtful if it ever takes place as an uncomplicated injury. (3) Fractures of the body of the ulna may occur at any part, but usually take place at or a little

below the middle of the bone. They are generally the result of direct violence, but may occur as a complication of dislocation of the radius. (4) The styloid process may be knocked off by direct violence.

The ulna may be exposed in its whole length by an incision along its dorsal border.

Fig. 390.—A plan of the ossification of the ulna. From three centres.

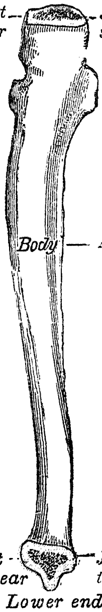
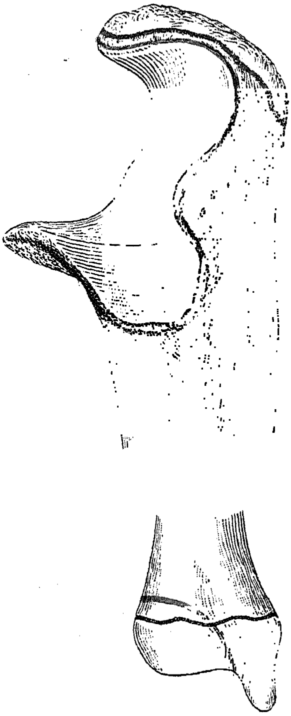


Fig. 391.—The epiphysial lines of the left ulna in a young adult. Lateral aspect.



The lines of attachment of the articular capsules are in blue.

Fractures of the radius may consist of: (1) Fracture of the head of the bone; this for the most part takes place in conjunction with some other lesion, but may occur as an uncomplicated injury. (2) Fracture of the neck also may occur, but is usually complicated with other injury. (3) Fractures of the body of the radius are very common, and may take place at any part of the bone. In fracture of the upper one-third of the body—that is to say, above the insertion of the Pronator teres—the displacement is very great. The upper fragment is strongly supinated by the Biceps and Supinator, and flexed by the Biceps; while the lower fragment is pronated and drawn towards the ulna by the two Pronators. If such a fracture be put up in the ordinary position, midway between supination and pronation, the bone will unite with the upper fragment in a position of supination, and the lower one in the mid-position, and thus considerable impairment of the movement of supination will result; the limb should therefore be put up with the forearm supinated. (4) The most important fracture of the radius is that of the lower end (Colles's fracture). The fracture is transverse, and generally takes place about 2·5 cm. from the lower end. It is caused by falls on the palm of the hand, and is an injury of advanced life, occurring more frequently in the female than in the male. In consequence of the manner in which the fracture is caused, the upper fragment is driven into the lower, and impaction commonly is the result; excess of violence may, however, disimpact, the lower fragment being split into two or more pieces, so that no fixation occurs. Separation of the lower epiphysis of the radius may take place in the young. This injury and Colles's fracture may be distinguished from other injuries in this neighbourhood—especially dislocation of the wrist, with which they are liable to be confounded—by observing the relative positions of the styloid processes of the ulna and radius. In the natural conditions of parts, with the arm hanging by the side, the styloid process of the radius is on a lower level than that of the ulna. After fracture or separation of the epiphysis the styloid process of the radius is on the same level as, or on a higher level than, that of the ulna, whereas it would be unaltered in position in dislocation. Reduction in the case of Colles's fracture is usually easily effected by traction on the hand, the

FIG. 392.—The bones of the left hand. Volar aspect.

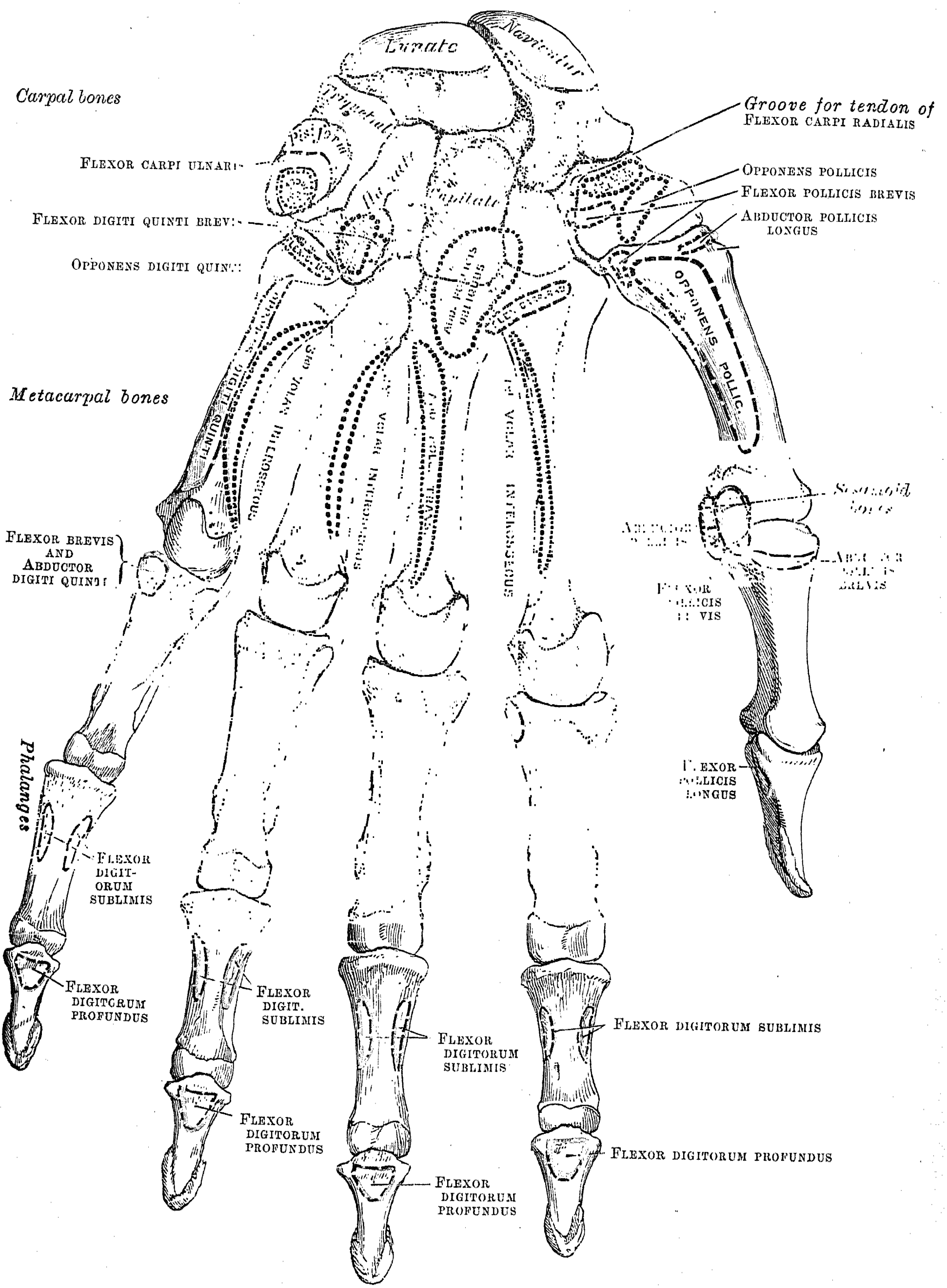
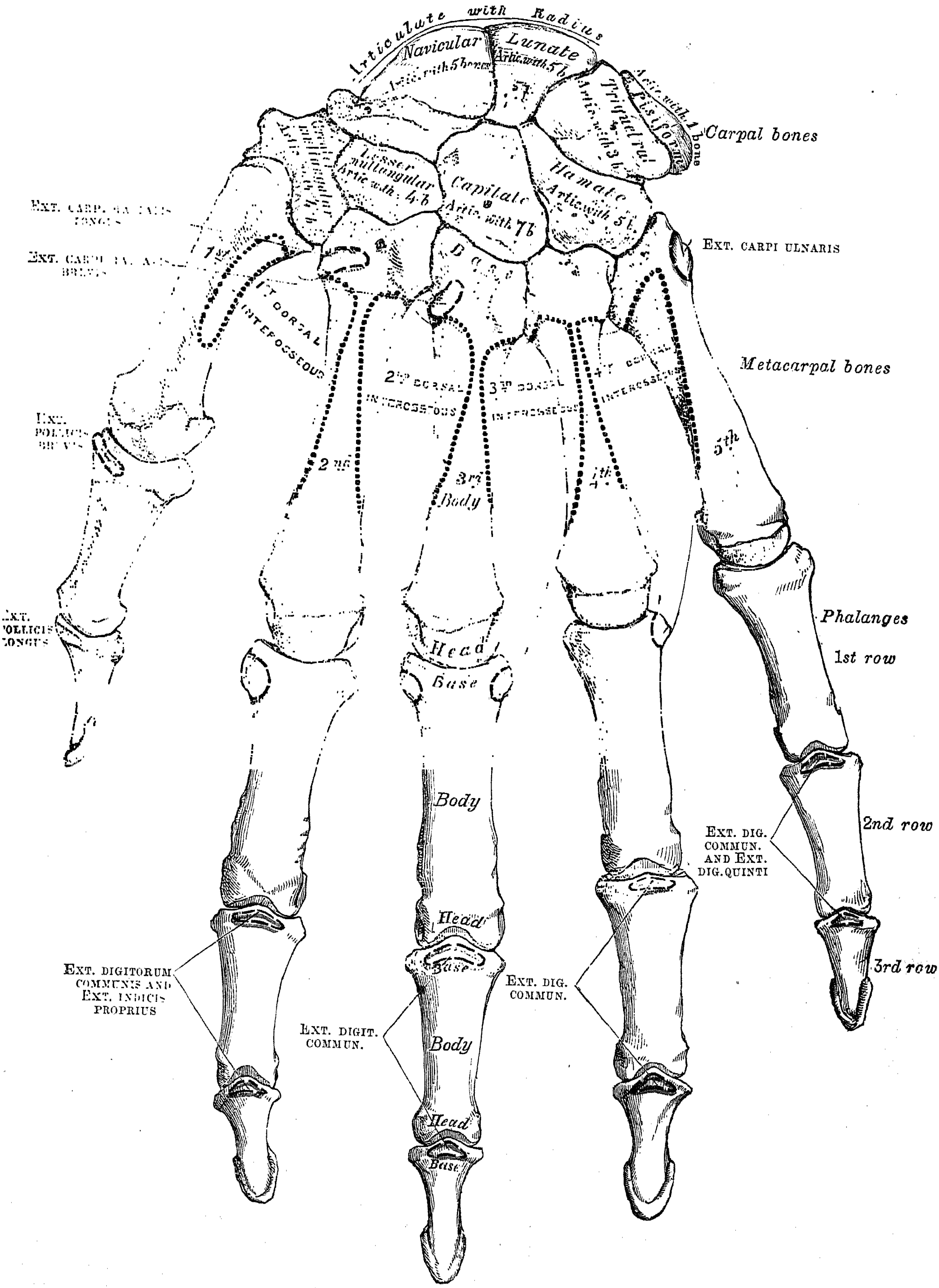


FIG. 393.—The bones of the left hand. Dorsal aspect.



limb being subsequently splinted with the hand deflected towards the ulnar side. Complete reduction is most important in this fracture, since any imperfection leads to impairment of mobility and function.

The upper one-third of the radius is exposed through an incision along the medial margin of the Brachioradialis, and then along the oblique line of the Radius. The Supinator, containing the deep branch (posterior interosseous branch) of the radial nerve is separated lateralwards, and the Flexores digitorum sublimis et profundus medialwards, from the bone.

THE SKELETON OF THE HAND

The skeleton of the hand (figs. 392, 393) consists of three segments : (1) the carpal or wrist bones ; (2) the metacarpal bones or bones of the palm ; and (3) the phalanges or bones of the digits.

The Carpal Bones (Ossa Carpi)

The **carpal bones,** eight in number, are arranged in two rows. Those of the proximal row, from the radial to the ulnar side, are named the navicular, lunate, triquetral, and pisiform bones ; those of the distal row, in the same order, are the greater multangular, lesser multangular, capitate, and hamate bones.

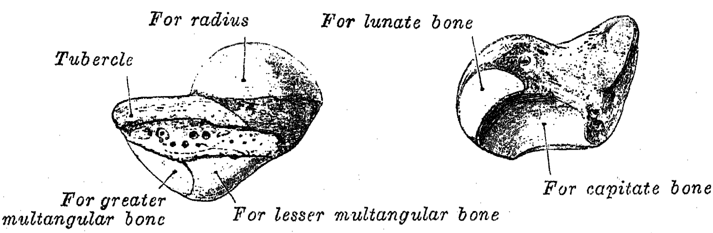
The Common Characteristics of the Carpal Bones

Each bone (excepting the pisiform) presents six surfaces. Of these the *volar or anterior* and the *dorsal or posterior surfaces* are rough, for ligamentous attachment ; the dorsal surfaces are the broader, except in the navicular and lunate bones. The *proximal or superior*, and *distal or inferior surfaces* are articular, the proximal generally convex, the distal concave ; the *medial and lateral surfaces* are also articular where they are in contact with contiguous bones, elsewhere they are rough and tuberculated.

The Navicular Bone (Os Naviculare Manus)

The **navicular bone** (fig. 394), the largest of the proximal row, has received its name from its fancied resemblance to a boat. It is situated at the radial side of the carpus, its long axis being from above downwards, lateralwards, and forwards. The *proximal surface*, convex, smooth, and of triangular shape,

Fig. 394.—The left navicular bone.



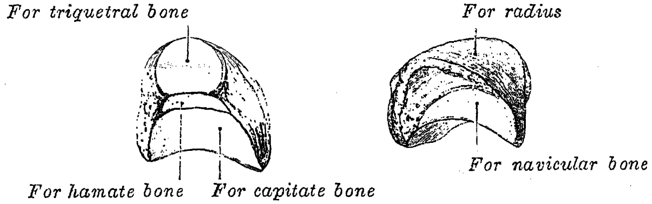
articulates with the lower end of the radius. The *distal surface*, directed downwards and backwards, is also smooth, convex, and triangular ; it is divided by an indistinct ridge into a lateral part which articulates with the greater multangular bone, and a medial with the lesser multangular bone.

On the *dorsal surface* is a narrow, rough groove which serves for the attachment of ligaments. The *volar surface* is concave above, but elevated at its lower and lateral part into a rounded *tubercle*, which is directed forwards and gives attachment to the transverse carpal ligament and sometimes to a few fibres of the Abductor pollicis brevis. The *lateral surface*, rough and narrow, gives attachment to the radial collateral ligament of the wrist. On the *medial surface* are two articular facets; of these, the proximal is flat and crescentic in shape, and articulates with the lunate bone; the distal is concave, and forms with the lunate bone a concavity for the head of the capitate bone.

The Lunate Bone (Os Lunatum)

The **lunate or semilunar bone** (fig. 395), distinguished by its deep concavity and crescentic outline, is situated in the centre of the proximal row of the carpus, between the navicular and triquetral bones. The *proximal surface*, convex and smooth, articulates with the radius. The *distal surface* is

Fig. 395.—The left lunate bone.



deeply concave from before backwards; it articulates with the head of the capitate bone by a large lateral facet, and with the hamate bone by a narrow, medial one. The *dorsal* and *volar surfaces* are rough, for the attachment of ligaments, the dorsal being the smaller. On the *lateral surface* is a semilunar facet for articulation with the navicular bone, and on the *medial surface* a quadrilateral facet for the triquetral bone.

The Triquetral Bone (Os Triquetrum)

The **triquetral or cuneiform bone** (fig. 396) may be distinguished by its pyramidal shape, and by an oval, isolated facet for articulation with the pisiform

Fig. 396.—The left triquetral bone.

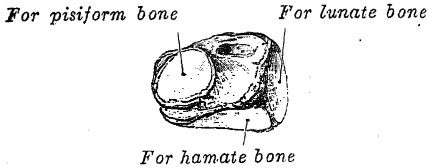
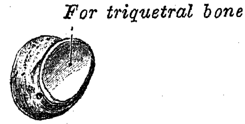


Fig. 397.—The left pisiform bone.



bone. It is situated at the ulnar side of the proximal row of the carpal bones with its long axis from above downwards and medialwards. The *proximal surface* presents a medial rough non-articular portion, and a lateral convex smooth portion which articulates with the triangular articular disc of the wrist. The *distal surface*, directed lateralwards, is concave, sinuously curved, and smooth for articulation with the hamate bone. The *dorsal surface* is rough for the attachment of ligaments. The *volar surface* displays, on its medial part, an oval facet for articulation with the pisiform bone; its lateral part is rough

for ligamentous attachment. The *lateral surface*, or base of the pyramid, is marked by a flat, quadrilateral facet for articulation with the lunate bone. The *medial surface*, or summit of the pyramid, is pointed and gives attachment to the ulnar collateral ligament of the wrist.

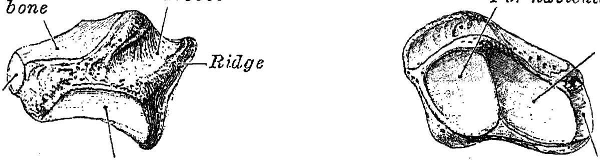
The Pisiform Bone (Os Pisiforme)

The **pisiform bone** (fig. 397) is situated in front of the triquetral bone, and may be known by its small size, and by its presenting a single, oval facet for articulation with that bone. This facet is on the *dorsal surface* of the bone, and its long axis is directed distalwards and lateralwards. The *volar surface* is round and rough, and gives attachment to the Flexor carpi ulnaris. The *medial surface* gives attachment to the Abductor digiti quinti and the dorsal carpal ligament; the pisometacarpal ligament is attached to the distal part of this surface. On the volar and lateral surfaces is an oblique line or ridge, the distal part of which gives attachment to the volar carpal ligament. The distal part of the bone projects beyond the articular surface and presents a tubercle for the attachment of the pisohamate ligament.*

The Greater Multangular Bone (Os Multangulum Majus)

The **greater multangular bone or trapezium** (fig. 398) may be distinguished by a deep groove on its volar surface. It is situated at the radial side of the carpus, between the navicular and first metacarpal bones. The *proximal surface* is directed upwards and medialwards; medially it is smooth,

Fig. 398.—The left greater multangular bone.



and articulates with the navicular bone; laterally it is rough and continuous with the lateral surface. The *distal surface* is oval, concave from side to side, convex from before backwards, so as to form a saddle-shaped surface for articulation with the base of the first metacarpal bone The *dorsal surface* is rough. The *volar surface* is narrow and rough. At its upper part is a deep groove, running from above downwards; it transmits the tendon of the Flexor carpi radialis, and is bounded laterally by a ridge which affords attachment to the transverse carpal ligament, and gives origin to the Opponens pollicis, Abductor pollicis brevis, and Flexor pollicis brevis. The *lateral surface* is broad and rough for the attachment of ligaments. On the *medial surface* are two facets; a proximal, large and concave, articulates with the lesser multangular bone; a distal, small and oval, with the base of the second metacarpal bone.

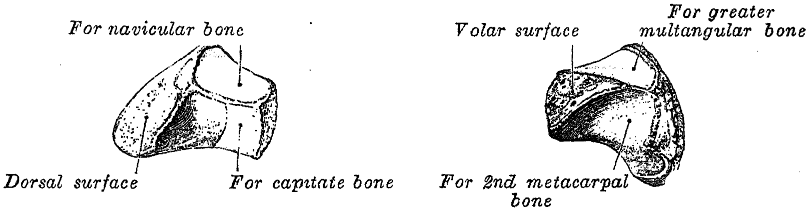
The Lesser Multangular Bone (Os Multangulum Minus)

The **lesser multangular or trapezoid bone** (fig. 399) is the smallest bone in the distal row. It may be known by its wedge-shaped form, the thick end of the wedge constituting the dorsal surface; and by its having four articular

* R. H. Robbins, *Journal of Anatomy and Physiology*, vol. li.

facets separated by sharp edges. The *proximal surface*, small, quadrilateral, and slightly concave, articulates with the navicular bone. The large *distal surface* articulates with the proximal end of the second metacarpal bone; it is convex from side to side, concave from before backwards. The *dorsal* and *volar surfaces* are rough for the attachment of ligaments, the former being the larger. The *lateral surface* is convex, and articulates with the greater multangular bone. The *medial surface* is concave and smooth in front, for articulation with the capitate bone; rough behind, for the attachment of an interosseous ligament.

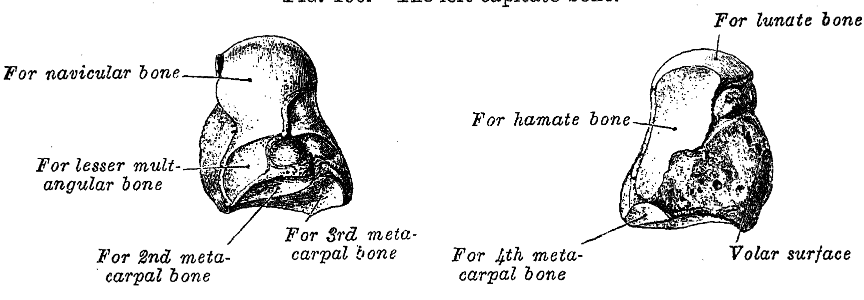
FIG. 399.—The left lesser multangular bone.



The Capitate Bone (Os Capitatum)

The **capitate bone or os magnum** (fig. 400) is the largest of the carpal bones, and occupies the centre of the wrist. It presents a rounded proximal portion, the head, which is received into the concavity formed by the navicular and lunate bones; a constricted portion, the neck; and a distal part, the body.

FIG. 400.—The left capitate bone.

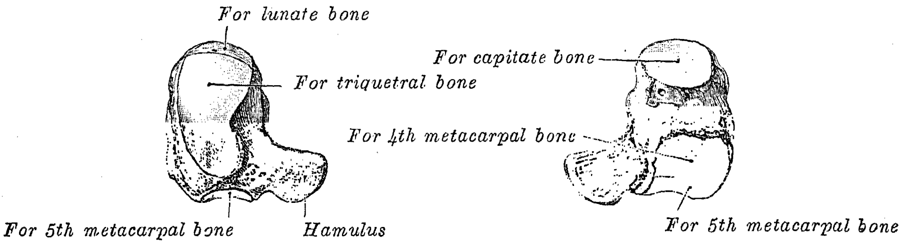


The *proximal surface* is round, smooth, and articulates with the lunate bone. The *distal surface* is divided by two ridges into three facets, for articulation with the second, third, and fourth metacarpal bones, that for the third being the largest. The *dorsal surface* is broad and rough. The *volar surface* is narrow, projecting and rough; it gives attachment to ligaments and to the oblique part of the Adductor pollicis. The *lateral surface* articulates, by a small facet at its volar distal angle, with the lesser multangular bone; dorsal to this facet is a rough depression for the attachment of an interosseous ligament. Proximal to this is a deep, rough groove, forming part of the neck, and serving for the attachment of ligaments; it is bounded proximally by a smooth, convex surface, for articulation with the navicular bone. The *medial surface* articulates with the hamate bone by a smooth, oblong facet which occupies the dorsal and proximal parts of this surface; its volar part is rough for the attachment of an interosseous ligament.

THE HAMATE BONE (OS HAMATUM)

The **hamate or unciform bone** (fig. 401) may be readily distinguished by its wedge-shaped form, and the hook-like process which projects from its volar surface. It is situated at the medial and distal part of the wrist, with its base directed distally, and its apex proximally and laterally. The *proximal surface* or apex of the wedge is convex, smooth, and articulates with the lunate bone. The *distal surface* articulates with the fourth and fifth metacarpal bones, by concave facets which are separated by a slight

FIG. 401.—The left hamate bone.



ridge. The *dorsal surface* is triangular, and rough for ligaments. From the distal and medial part of the *volar surface* a curved, hook-like process, the *hamulus*, is directed forwards and lateralwards. This process gives attachment, by its apex, to the transverse carpal ligament and the Flexor carpi ulnaris; by its medial surface to the Flexor brevis and Opponens digiti quinti; its lateral side is grooved for the passage of the flexor tendons into the palm of the hand. The *medial surface* articulates with the triquetral bone by an oblong, obliquely-cut facet. The proximal and dorsal parts of the *lateral surface* articulate with the capitate bone; the rest of the surface is rough for the attachment of ligaments.

THE METACARPAL BONES (OSSA METACARPI)

The **metacarpal bones** (figs. 392, 393), five in number, are enumerated from the lateral side.

THE COMMON CHARACTERISTICS OF THE METACARPAL BONES

Each metacarpal bone has a body, a base or proximal end, and a head or distal end.

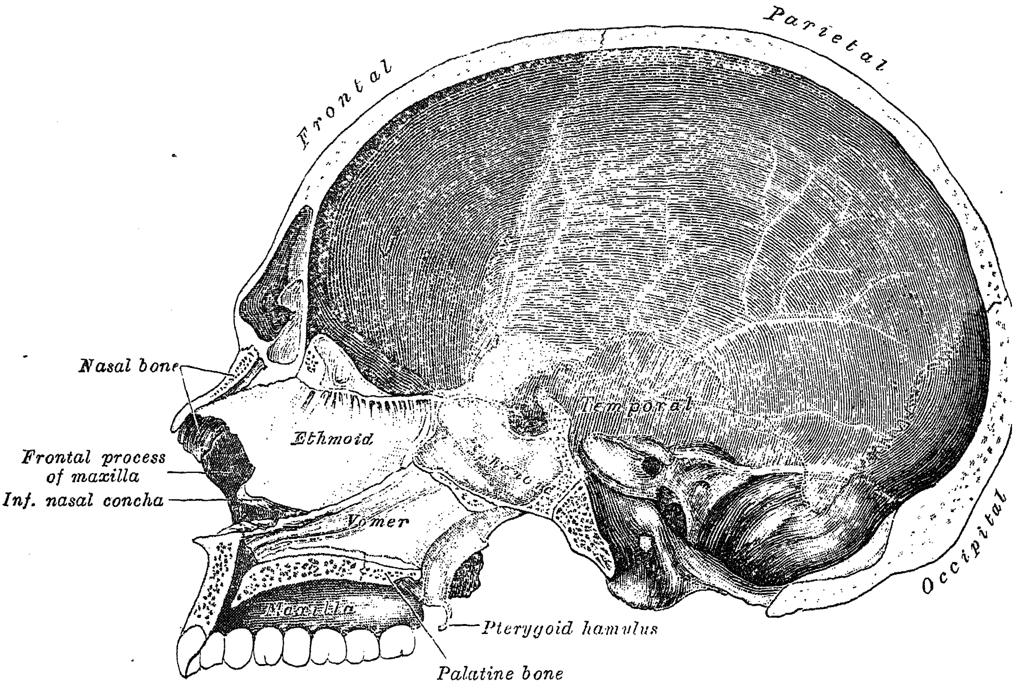
The **body** of each bone is prismoid in form, and curved, so as to be convex longitudinally behind, concave in front. It has three surfaces: medial, lateral, and dorsal. The *medial* and *lateral surfaces* are concave, for the attachment of the Interossei, and separated from one another by a prominent volar ridge. The *dorsal surface* presents in its distal two-thirds a smooth, triangular, flattened area which is covered, in the recent state, by the tendons of the extensor muscles. This surface is bounded by two lines, which commence in small tubercles situated at the sides of the head, and converge and meet some distance above the centre of the bone to form a ridge which is continued to the base. This ridge separates two sloping surfaces for the attachment of the Interossei dorsales. To the tubercles at the head are attached the collateral ligaments of the metacarpophalangeal joints.

The **base** is of a cuboidal form, and broader behind than in front: it articulates with one or more of the carpal bones, and with the contiguous metacarpal bones; its *dorsal* and *volar surfaces* are rough, for the attachment of ligaments.

The **head** presents an oblong surface markedly convex from before backwards, less so transversely; it articulates with the proximal phalanx. It

and some meningeal branches from the occipital and ascending pharyngeal arteries; and the intermediate portion, the glossopharyngeal, vagus, and accessory nerves. Above the jugular foramen is the opening of the internal acoustic meatus, for the facial and acoustic nerves and the internal auditory artery; posterior and lateral to this opening is the slit leading to the aquæductus vestibuli which lodges the ductus endolymphaticus. Near the superior angle (margin) of the petrous portion, is a small depression, the remains of the fossa subarcuata, which lodges a process of the dura mater and transmits one

Fig. 363.—A sagittal section through the skull.



or more small veins. Behind the foramen magnum is the internal occipital crest which serves for the attachment of the falx cerebelli; in the attached margin of this falx is the occipital sinus, which is sometimes duplicated. Lateral to the crest are the inferior occipital fossæ, which support the hemispheres of the cerebellum and are limited behind by the transverse sulci. Each transverse sinus grooves successively the occipital bone, the mastoid angle of the parietal bone, the mastoid portion of the temporal bone, and the jugular process of the occipital bone, and ends at the posterior part of the jugular foramen. Where the sinus grooves the mastoid portion of the temporal bone, the orifice of the mastoid foramen may be seen; and, just behind the jugular foramen, the condyloid canal may open into it; neither opening is constant.

The Nasal Cavities

The **nasal cavities** are two irregular spaces, situated one on either side of the middle line of the face, extending from the base of the cranium to the roof of the mouth, and separated from each other by a thin vertical septum. They open on the face through the pear-shaped anterior nasal aperture, and their posterior openings, or choanæ, communicate, in the recent state, with the nasal part of the pharynx. They are narrower above than below, and in the middle than at their anterior or posterior openings: their depth is greatest in the middle. They communicate with the frontal, ethmoidal, sphenoidal, and maxillary air-sinuses.

on the proximal surface the intermediate is the largest and is concave from side to side, convex from before backwards, for articulation with the lesser multangular bone; the lateral is small, flat and oval for articulation with the greater multangular bone; the medial, on the summit of the ridge, is long and narrow for articulation with the capitate bone. The facet on the medial side articulates with the third metacarpal bone. The Extensor carpi radialis longus is inserted on the lateral part of the dorsal surface, and the Flexor carpi radialis on the volar surface, of the base.

The **third metacarpal bone** (fig. 404) is a little smaller than the second. On the lateral side of the dorsal part of its *base* is a pyramidal eminence, the *styloid process*; immediately distal to this is a rough surface for the attachment of the Extensor carpi radialis brevis. The proximal articular facet is concave dorsally, and articulates with the capitate bone. On the lateral side is a smooth, concave facet for articulation with the second metacarpal bone, and on the medial side two small oval facets for the fourth metacarpal bone.

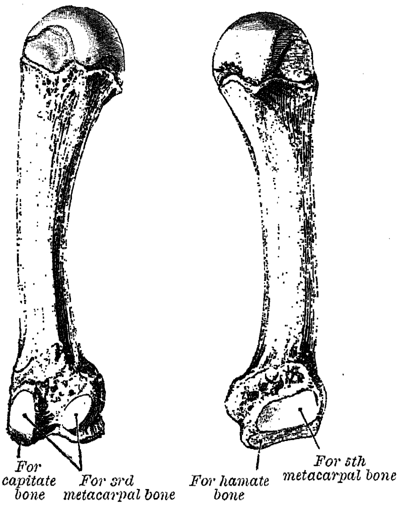


Fig. 405.—The fourth left metacarpal bone.

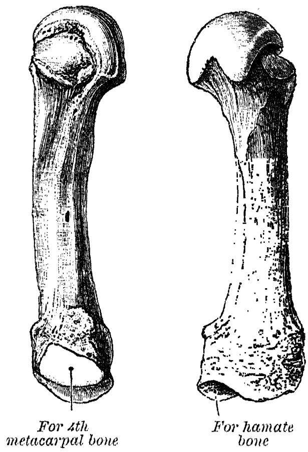


Fig. 406.—The fifth left metacarpal bone.

The **fourth metacarpal bone** (fig. 405) is shorter than the third. Its *base* is small and quadrilateral; on its proximal surface are two facets, a large medial one for articulation with the hamate bone, and a small one at the dorsolateral angle for the capitate bone. On the lateral side are two oval facets, for articulation with the third metacarpal bone; and on the medial side, a single concave facet, for the fifth metacarpal bone.

The **fifth metacarpal bone** (fig. 406) has two facets on its *base*; that on its proximal surface is saddle-shaped, and articulates with the hamate bone; that on the lateral side articulates with the fourth metacarpal bone On its medial side is a tubercle for the insertion of the tendon of the Extensor carpi ulnaris. The dorsal surface of the body is divided by an oblique ridge, which extends from near the medial side of the base to the lateral side of the head. The lateral part of this surface serves for the attachment of the fourth Interosseus dorsalis; the medial part, smooth and triangular, is covered by the extensor tendons of the little finger.

The Phalanges of the Hand (Phalanges Digitorum Manus)

The **phalanges** are fourteen in number, three for each finger, and two for the thumb. Each consists of a body and two ends. The *body* tapers towards its distal end, and its dorsal surface is convex; its volar surface is concave longitudinally, and flat from side to side; its sides are marked by rough ridges, which give attachment to the fibrous sheaths of the flexor tendons. The

proximal ends of the bones of the first row present oval, concave articular surfaces, broader from side to side than from before backwards. On the proximal end of each of the bones of the second and third rows are two concavities separated by a median ridge. The *distal ends* are smaller than the proximal, and each terminates in two condyles separated by a shallow groove; the articular surface extends farther on the volar than on the dorsal surface, a condition best marked in the bones of the first row.

The *ungual phalanges* are convex on their dorsal, and flat on their volar surfaces; they are recognised by their small size, and by a rough, elevated surface of a horseshoe form on the volar surface of the distal end of each, which serves to support the sensitive pulp of the finger.

The Ossification of the Bones of the Hand

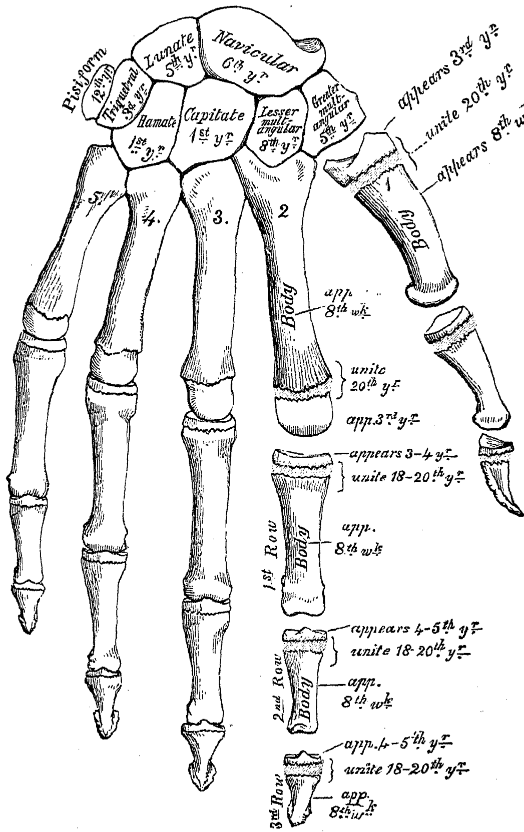
The **carpal bones** are each ossified from a single centre, and ossification proceeds in the following order (fig. 407): in the capitate and hamate bones, during the first year; in the triquetral bone, during the third year; in the lunate and greater

Fig. 407.—A plan of the ossification of the bones of the hand.

CARPAL BONES
One centre for each bone:
All cartilaginous at birth

METACARPAL BONES
Two centres for each bone:
One for body
One for head

PHALANGES
Two centres for each bone:
One for body
One for proximal end



multangular bones, during the fifth year; in the navicular bone, during the sixth year; in the lesser multangular bone, during the eighth year; and in the pisiform bone, about the twelfth year.

Occasionally an additional bone, the *os centrale*, is found between the navicular, lesser multangular, and capitate bones. During the second month of fœtal life it is represented by a small cartilaginous nodule, which usually fuses with the cartilaginous navicular. Sometimes the styloid process of the third metacarpal bone is detached and forms an additional ossicle.

The **metacarpal bones** are each ossified from two centres; a primary centre for the body, and a secondary or epiphysial centre for the base or proximal end of the first and for the head or distal end of each of the other four.* The first metacarpal bone is therefore ossified in the same manner as the phalanges, and this has led some anatomists to regard the thumb as being made up of three phalanges, and not of a metacarpal bone and two phalanges. Ossification begins in the middle of the body about the eighth or ninth week of fœtal life, the centres for the second and third metacarpal bones being the first, and that for the first metacarpal bone the last, to appear. About the third year the base of the first metacarpal bone, and the heads of the other metacarpal bones, begin to ossify; they unite with the bodies about the twentieth year.

The **phalanges** are each ossified from two centres; a primary centre for the body, and a secondary or epiphysial centre for the proximal extremity. Ossification begins in the body about the eighth week of fœtal life. The epiphyses for the bases of the first row of phalanges appear between the third and fourth years, and those for the second and third rows of phalanges a year later. All unite with the bodies between the eighteenth and twentieth years.

In the ungual phalanges the centres for the bodies appear at the distal ends of the phalanges, instead of at the middle of the bodies, as in the other phalanges. Moreover, of all the bones of the hand, the ungual phalanges are the first to ossify.

Applied Anatomy.—The use of X-rays has shown that the carpal bones are more frequently fractured than was formerly supposed. When a single bone is broken it is usually the navicular or the capitate (more frequently the former) and the fracture runs at right angles to the long axis of the bone. There are two diseases of the metacarpal bones and phalanges which require special mention on account of their frequent occurrence. One is tuberculous dactylitis, consisting of a deposit of tuberculous material in the medullary canal, expansion of the bone, with subsequent caseation and necrosis. The other is chondroma, which is perhaps more commonly found in connexion with the metacarpal bones and phalanges than with any other bones. The tumours are usually multiple, and spring from beneath the periosteum about the epiphysial plate. In osteoarthritis small symmetrical bony outgrowths known as "Heberden's nodes," often appear on the dorsal aspects of the terminal joints of the fingers, with radial deflection of the terminal phalanges in advanced cases. These nodes are usually painless, but cause inconvenience by limiting the mobility of the finger-tips.

THE BONES OF THE INFERIOR EXTREMITY

THE HIP-BONE (OS COXÆ)

The **hip-bone** (os innominatum) (figs. 408, 409) is a large, flattened, irregularly shaped bone, constricted in the centre and expanded above and below. It articulates in front with the bone of the opposite side, and the two bones form the pelvic girdle or girdle of the inferior extremity. The hip-bone consists of three parts, the ilium, ischium, and os pubis, which are distinct from each other in the young subject, but are united in the adult; the union of the three parts takes place in and close to a large cup-shaped articular cavity, the acetabulum, which is situated near the middle of the outer surface of the bone.

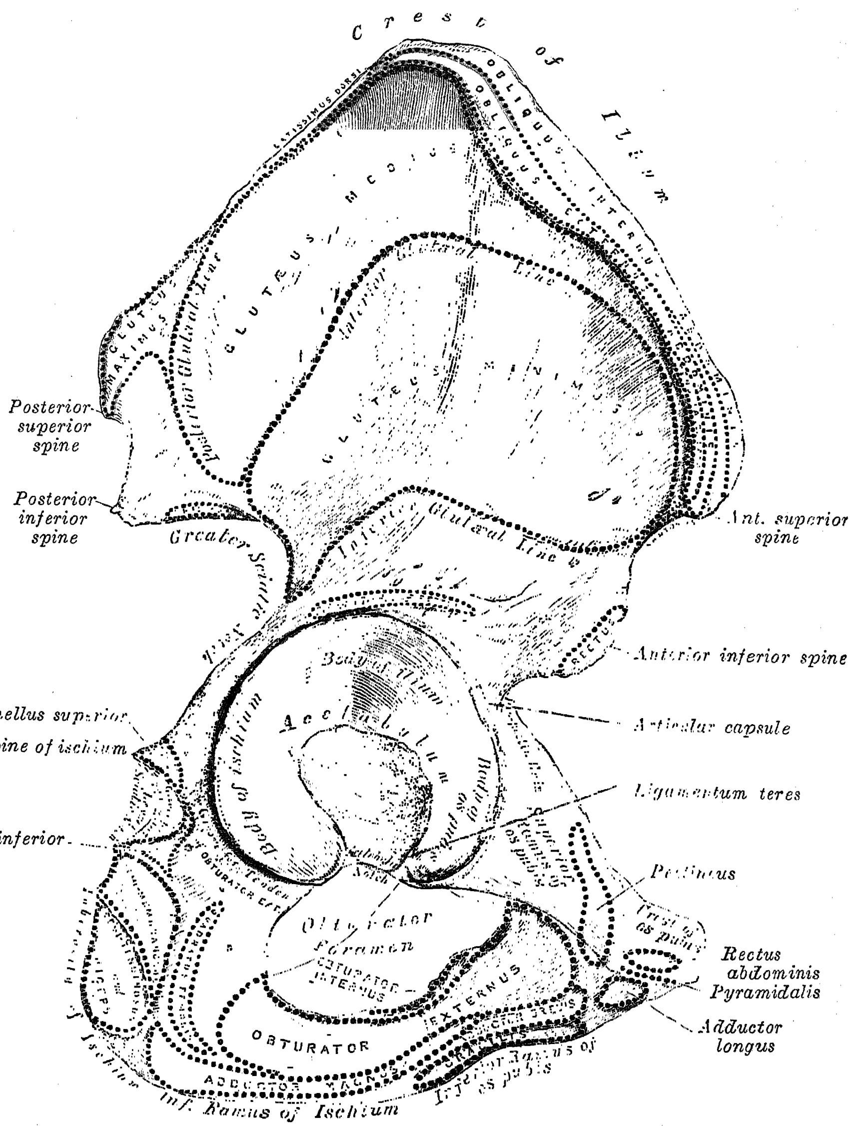
The **ilium** (os ilii) so named because it supports the flank, is the broad and expanded portion of the hip-bone which extends upwards from the acetabulum. It is divisible into two parts, the body and the ala, which are separated on the internal surface of the bone by a curved line, the *arcuate line*, and on the external surface by the upper part of the margin of the acetabulum.

The **body** of the ilium forms rather less than two-fifths of the acetabulum. Its *external surface* is partly articular, partly non-articular; the articular

* Allen Thomson (*Journal of Anatomy and Physiology*, vol. iii. 1869) pointed out that the first metacarpal bone is often developed from three centres; that is to say, there is a separate centre for the distal end, forming a distinct epiphysis visible at the age of seven or eight years. He also stated that there are traces of a proximal epiphysis in the second metacarpal bone.

segment forms part of the lunate surface of the acetabulum, the non-articular portion contributes to the acetabular fossa. The *internal surface* of the body is a part of the wall of the lesser pelvis; it gives origin to some fibres of the Obturator internus, and is continuous below with the pelvic surfaces of the ischium and os pubis.

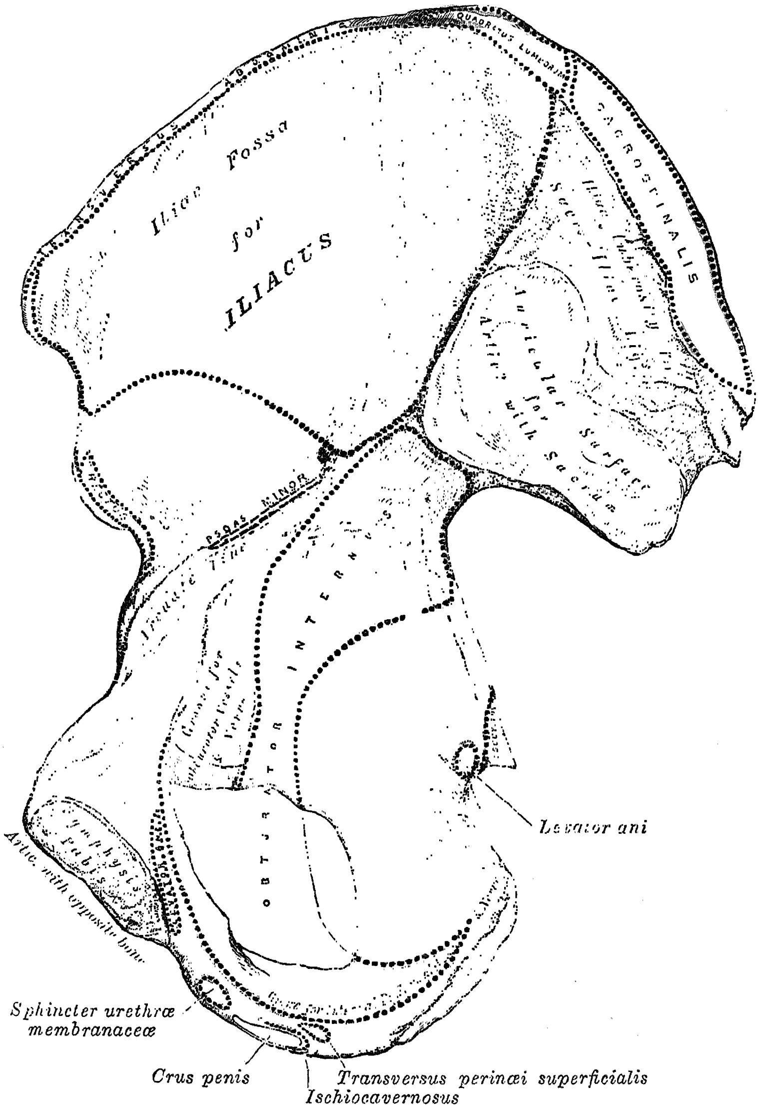
FIG. 408.—The right hip-bone. External surface.



The ala of the ilium, the large expanded portion, bounds the greater pelvis laterally. It has an external and an internal surface, a crest, and an anterior and a posterior border. The *external surface*, or *dorsum* (fig. 408), is directed backwards and lateralwards behind, and lateralwards and downwards in front. It is smooth, convex in front, concave behind, and is bounded above by the crest, below by the upper border of the acetabulum, and in front and behind by the anterior and posterior borders. This surface is crossed by the posterior, anterior, and inferior glutæal lines. The *posterior glutæal line* (superior curved line), the shortest of the three, begins above at the crest, about 5 cm. in front of its posterior extremity, and ends below at the upper part of the greater

sciatic notch; its upper part is well-marked, but its lower part is ill-defined and frequently absent. Behind this line is a narrow, semilunar surface, the upper part of which is rough and gives origin to a portion of the Glutæus maximus; the lower part is smooth, and has no muscular fibres attached to it. The *anterior glutæal line* (middle curved line), the longest of the three,

FIG. 409.—The right hip-bone. Internal surface.



begins near the crest, about 4 cm. behind its anterior extremity, and, curving backwards and downwards, ends at the upper part of the greater sciatic notch; a nutrient foramen is often seen near the middle of this line. The surface between the crest and the anterior and posterior glutæal lines, gives origin to the Glutæus medius. The *inferior glutæal line* (inferior curved line), the least distinct, begins in front at the notch on the anterior border, and, curving backwards and downwards, ends near the middle of the greater sciatic notch; the Glutæus minimus takes origin between the anterior and inferior glutæal lines. Immediately above the acetabulum is a rough shallow groove from which the reflected tendon of the Rectus femoris takes origin.

The medial fragment, as a rule, is little displaced. The main vessels of the upper limb and the great nerve-cords of the brachial plexus lie beneath the bone on the first rib and are liable to be wounded, especially in fracture from direct violence, when the force of the blow drives the broken ends inwards. Fortunately the Subclavius intervenes between these structures and the clavicle, and often protects them from injury.

The clavicle is occasionally the seat of sarcomatous tumours, rendering the operation of excision of the entire bone necessary. This is an operation of considerable difficulty and danger. It is best performed by exposing the bone freely, disarticulating at the acromial end, and turning it forwards. The removal of the lateral part is comparatively easy, but resection of the medial part is fraught with difficulty, the main danger being the risk of wounding the great veins which are in relation with its deep surface.

Great deformity of the clavicle may be met with in rickets, the natural curvatures of the bone being exaggerated until it takes an S shape, and 'green-stick' fracture is not uncommonly seen associated therewith.

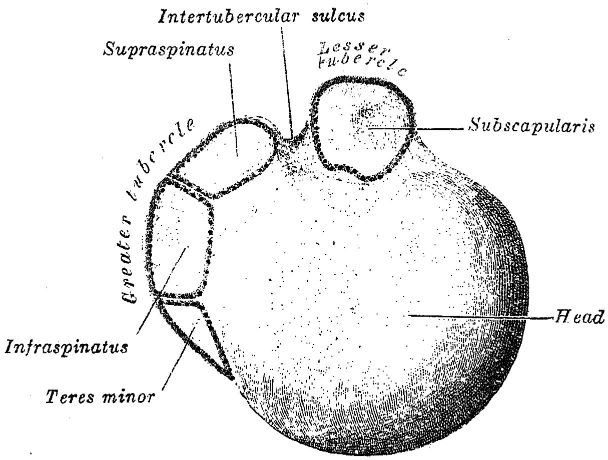
The Humerus

The **humerus** (figs. 377, 378), the longest and largest bone of the upper limb, is divisible into a body or shaft, and two ends.

The **upper end** consists of the *head* and the *greater* and *lesser tubercles*.

The **head** of the humerus (fig. 376), nearly hemispherical in form, is directed upwards, medialwards, and a little backwards ; it articulates with

Fig. 376.—The upper end of the left humerus. Superior aspect.



the glenoid cavity of the scapula. The circumference of its articular surface is slightly constricted, and is termed the *anatomical neck,* in contradistinction to a constriction below the tubercles, which is called the *surgical neck* because it is frequently the seat of fracture.

The *anatomical neck* forms an obtuse angle with the body and is best marked in the lower half of its circumference ; in the upper half it is represented by a narrow groove separating the head from the tubercles. It affords attachment to the articular capsule of the shoulder-joint, and is perforated by foramina for the transmission of blood-vessels.

The *greater tubercle* is lateral to the head and lesser tubercle. Its upper surface is convex and marked by three impressions ; the highest of these gives insertion to the Supraspinatus ; the middle, to the Infraspinatus ; the lowest, and the bone for about 2·5 cm. distal to it, to the Teres minor. The lateral surface of the greater tubercle is convex, rough, and continuous with the lateral surface of the body.

The *lesser tubercle,* more prominent than the greater, is situated in front, and is directed forwards and medialwards. On its upper and front part is an impression for the insertion of the tendon of the Subscapularis.

nerve, and the nerves to the Obturator internus and Quadratus femoris. Of these, the superior glutæal vessels and nerve emerge above the Piriformis, the other structures below it. Below the spine is the *lesser sciatic notch* ; it is converted into a foramen by the sacrotuberous and sacrospinous ligaments, and transmits the tendon of the Obturator internus, the nerve which supplies that muscle, and the internal pudendal vessels and pudendal nerve.

The **superior ramus** of the ischium projects downwards and backwards from the body and has three surfaces : external, internal, and posterior. The *external surface* is quadrilateral in shape, and on its upper part is a groove which lodges the tendon of the Obturator externus. Below, it is continuous with the external surface of the inferior ramus ; in front, it is limited by the posterior margin of the obturator foramen ; behind, a prominent margin separates it from the posterior surface. In front of the latter margin the external surface gives origin to the Quadratus femoris, and to some of the fibres of the Obturator externus ; its lower part gives origin to a portion of the Adductor magnus. The *internal surface* forms a part of the bony wall of the lesser pelvis. In front it is limited by the posterior margin of the obturator foramen. Below and behind, it is bounded by a sharp ridge which gives attachment to the falciform process of the sacrotuberous ligament ; more anteriorly it gives origin to the Transversus perinæi superficialis and the Ischiocavernosus.

The *posterior surface* of the superior ramus forms a large swelling, the *tuberosity of the ischium*, which consists of two portions : a lower, rough, triangular part, and an upper, smoother, quadrilateral portion. The lower, triangular portion is subdivided by a prominent longitudinal ridge into two parts ; the lateral part gives attachment to the Adductor magnus, the medial to the sacrotuberous ligament. The upper, quadrilateral portion is subdivided into two areas by an oblique ridge which runs downwards and lateralwards ; from the upper and lateral area the Semimembranosus arises ; from the lower and medial area, the Semitendinosus and the long head of the Biceps femoris.

The **inferior ramus** is the thin, flattened part of the ischium, which passes forwards from the superior ramus, and joins the inferior ramus of the os pubis, the junction being indicated on the external surface by a raised line. Its *external surface* is uneven for the origin of the Obturator externus and some of the fibres of the Adductor magnus ; its *internal surface* forms part of the anterior wall of the pelvis and gives attachment to the Sphincter urethræ membranaceæ. The *lower border* of the inferior ramus is thick, rough, slightly everted. It forms part of the outlet of the pelvis, and presents two slight ridges and an intervening space. The ridges are continuous with similar ones on the inferior ramus of the os pubis ; to the outer is attached the deep layer of the superficial perinæal fascia (fascia of Colles), and to the inner the inferior fascia of the urogenital diaphragm. When traced backwards these two ridges join ; from the space just in front of their junction the Transversus perinæi superficialis takes origin, and in front of this the Ischiocavernosus and the crus penis vel clitoridis are attached. The *upper border* of the inferior ramus is thin, and forms part of the medial margin of the obturator foramen.

The **os pubis,** the anterior part of the hip-bone, is divisible into a body, and a superior and an inferior ramus.

The **body** of the os pubis forms one-fifth of the acetabulum, contributing by its *external surface* both to the lunate surface and to the acetabular fossa. Its *internal surface* enters into the formation of the wall of the lesser pelvis. Its *anterior surface* is marked by a rough eminence, the *iliopectineal eminence*, which indicates the junction of the ilium with the os pubis.

The **superior ramus** of the os pubis extends from the body to the median plane, where it articulates with the superior ramus of the opposite os pubis. It is conveniently described in two portions, viz. a medial flattened part and a narrow lateral prismoid portion.

The *medial portion* of the superior ramus, formerly described as the body of the os pubis, is somewhat quadrilateral in shape, and has two surfaces and three borders. The *external surface* is directed downwards and lateralwards, and serves for the origin of various muscles. The Adductor longus arises from the anterior and medial angle, immediately below the crest ; more posteriorly, the Obturator externus, the Adductor brevis, and the upper part

of the Gracilis take origin. The *internal surface*, convex from above downwards, concave from side to side, is smooth, and forms part of the anterior wall of the lesser pelvis. It gives origin to parts of the Levator ani and Obturator internus, and attachment to the puboprostatic ligaments and to a few muscular fibres prolonged from the bladder. On the *upper border* is a prominent tubercle, the *pubic tubercle* (pubic spine) which projects forwards and gives attachment to the inguinal ligament (Poupart's ligament). Passing upwards and lateralwards from the pubic tubercle is a well-defined ridge, the *pecten pubis*, which forms a part of the brim of the lesser pelvis; to it are attached a portion of the inguinal falx (conjoined tendon of Obliquus internus and Transversus), the lacunar ligament (Gimbernat's ligament), and the reflected inguinal ligament (triangular fascia). Medial to the pubic tubercle is the *pubic crest*, which extends from the tubercle to the medial border of the bone; it affords attachment to the inguinal falx, and to the Rectus abdominis and Pyramidalis. The point of junction of the crest with the medial border of the bone is called the *angle*; a part of the superior crus of the subcutaneous inguinal ring is attached to it. The *medial border* is articular; it is oval, and is marked by eight or nine transverse ridges, or a series of nipple-like processes arranged in rows; they serve for the attachment of a thin layer of cartilage, which is fixed to that of the opposite pubic bone by the interpubic fibrocartilaginous lamina. The *lateral border* presents a sharp margin, the *obturator crest*, which forms part of the circumference of the obturator foramen and affords attachment to the obturator membrane.

The *lateral portion* of the superior ramus has an internal and an external surface, separated by the pecten pubis. The *internal surface* constitutes a part of the anterior boundary of the lesser pelvis, and affords origin to some fibres of the Obturator internus. The *external surface* consists of an anterosuperior and a postero-inferior part, separated by a prominent ridge which extends from the anterior margin of the acetabular notch to the pubic tubercle. The anterosuperior part, triangular in form, is limited above by the *iliopectineal eminence* (p. 309), and is covered by the Pectineus. The postero-inferior part, also triangular in form, is directed towards the obturator foramen; on it is a broad, deep groove, the *obturator groove*, for the lodgment of the obturator vessels and nerve.

The **inferior ramus** of the os pubis is thin and flattened. It passes lateralwards and backwards from the medial part of the superior ramus, narrows as it recedes and joins with the inferior ramus of the ischium below the obturator foramen. Its *external surface*, directed forwards and downwards, is rough for the origin of the following muscles, viz.—the Gracilis along its medial border, a portion of the Obturator externus near the obturator foramen, and between these two muscles, the Adductores brevis et magnus, the former being the more medial. The *internal surface*, directed backwards and upwards, is smooth, and gives origin to the Obturator internus, and, close to the medial border, to the Sphincter urethræ membranaceæ. The *medial border* is thick, rough, and everted. It presents two ridges, separated by an intervening space. The ridges extend downwards, and are continuous with similar ridges on the inferior ramus of the ischium (p. 310); to the external is attached the superficial perinæal fascia (fascia of Colles), and to the internal the inferior fascia of the urogenital diaphragm. The *lateral border* is thin and sharp, forms part of the circumference of the obturator foramen, and gives attachment to the obturator membrane.

The **acetabulum** of the hip-bone (fig. 408) is a deep, cup-shaped, hemispherical depression, which looks downwards, lateralwards, and forwards. It is formed above by the ilium, medially by the os pubis, posteriorly and below by the ischium; a little less than two-fifths is contributed by the ilium, a little more than two-fifths by the ischium, and one-fifth by the os pubis. It is surrounded by a prominent, uneven rim, which is thick and strong above, and serves for the attachment of the glenoidal labrum (cotyloid ligament), which contracts the orifice of the acetabulum, and deepens the surface for articulation. It presents below, a deep notch, the *acetabular notch*, which is continuous with a nearly circular non-articular depression, the *acetabular fossa*, at the bottom of the cavity; this fossa is perforated by apertures for vessels, and lodges a mass of fat. The notch is converted into a foramen by the transverse acetabular

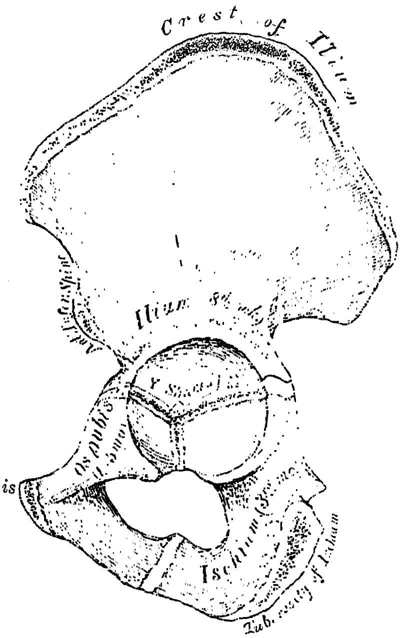
ligament, and through the foramen nutrient vessels and nerves enter the joint; the margins of the notch serve for the attachment of the ligamentum teres. The rest of the acetabulum consists of a horse-shoe shaped articular surface, the *lunate surface*, for articulation with the head of the femur.

The **obturator foramen** of the hip-bone is an aperture between the ischium and os pubis. In the male it is large and of an oval form, its longest diameter slanting obliquely from before backwards; in the female it is smaller, and more triangular. It is bounded by a thin, uneven margin, to which the obturator membrane is attached, and it presents, superiorly, a deep groove, the *obturator groove*, which runs downwards and medialwards from the pelvis. This groove is converted into a canal by a ligamentous band, which consists of a specialised part of the obturator membrane, and is attached to two tubercles: one, the

FIG. 410.—A plan of the ossification of the hip-bone.

By eight centres { *Three primary, for the ilium, ischium, and os pubis.* / *Five secondary.* }

Symphysis pubis



The three primary centres unite through the Y shaped piece about puberty. Secondary centres appear about puberty, and unite about the 25th year.

posterior obturator tubercle, just below the acetabular notch; the other, the *anterior obturator tubercle*, on the obturator crest (p. 311) of the superior ramus of the os pubis. Through the canal the obturator vessels and nerve pass out of the pelvis.

Structure.—The thicker parts of the hip-bone consist of spongy substance, enclosed between two layers of compact bone; the thinner parts, as at the bottom of the acetabulum and centre of the iliac fossa, are usually semitransparent, and composed entirely of compact bone.

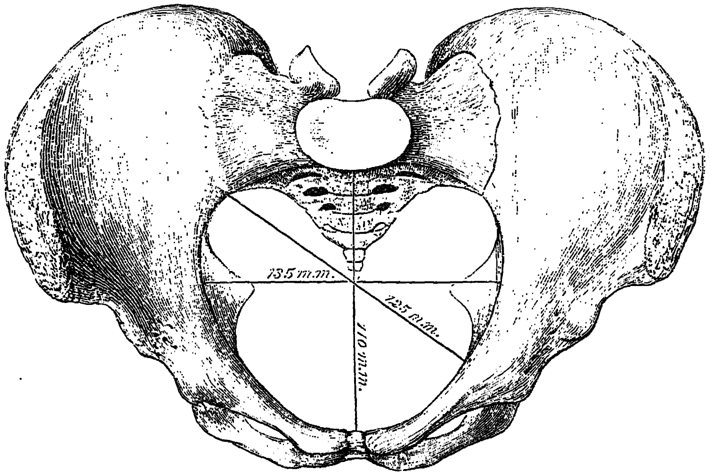
Ossification (fig. 410).—The hip-bone is ossified from eight centres: three primary, one each for the ilium, ischium, and os pubis; and five secondary, one each for the crest of the ilium, the anterior inferior iliac spine (said to occur more frequently in the male than in the female), the tuberosity of the ischium, the pubic symphysis (more frequent in the female than in the male), and one or more for the **Y**-shaped piece at the bottom of the acetabulum. The centres appear in the following order: in the ilium, immediately above the greater sciatic notch, about the eighth or ninth week of fœtal life; in the superior ramus of the ischium, about the third month; in the superior ramus of the os pubis, between the fourth and fifth months. At birth, the iliac crest, the greater part of the acetabulum, the ischial tuberosity,

and the inferior rami of the ischium and os pubis are cartilaginous. By the seventh or eighth year, the inferior rami of the os pubis and ischium are almost completely united by bone. The three primary centres extend their growth into the bottom of the acetabulum, where they are separated from each other by a Y-shaped portion of cartilage which begins to ossify by two or more centres in the twelfth year. One of these centres, the *os acetabuli*, forms the pubic part of the acetabulum and fuses with the main parts of the bone about puberty. The ilium and ischium then become joined, and lastly the os pubis and ischium, through the intervention of this Y-shaped portion. At about the age of puberty, ossification takes place in each of the remaining portions, and they join with the rest of the bone between the twentieth and twenty-fifth years. Separate centres are frequently found for the tubercle, crest and angle of the os pubis, and the spine of the ischium.

The Pelvis

The **pelvis,** so called from its resemblance to a basin, is a massive bony ring, interposed between the movable segments of the vertebral column which it supports, and the lower limbs upon which it rests ; it is composed of the

Fig. 411.—The diameters of the superior aperture of the lesser pelvis (female).



two hip-bones laterally and in front, and the sacrum and coccyx behind. It is divided into the greater and the lesser pelvis by an oblique plane passing through the prominence of the sacrum behind, the arcuate line and pecten pubis laterally, and the upper margin of the symphysis pubis in front. The circumference of this plane is termed the *pelvic brim.*

The **greater pelvis** (pelvis major), the expanded portion of the cavity above and in front of the pelvic brim, is formed on either side by the ilium and posteriorly by the base of the sacrum.

The **lesser pelvis** (pelvis minor) is that part of the pelvic cavity which lies below and behind the pelvic brim. Its bony walls are more complete than those of the greater pelvis. It possesses an inlet bounded by the superior circumference, an outlet bounded by the inferior circumference, and a cavity.

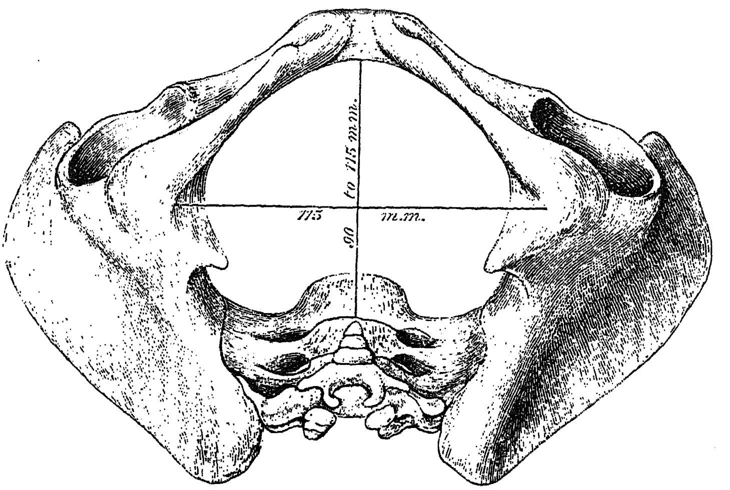
The *superior circumference* forms the brim of the pelvis, the included space being called the *superior aperture* or *inlet* (fig. 411). The superior aperture is somewhat heart-shaped, obtusely pointed in front, and encroached upon behind by the forward projection of the promontory of the sacrum. It has three principal diameters : anteroposterior, transverse, and oblique. The *anteroposterior or conjugate diameter* extends from the sacrovertebral angle to the symphysis pubis ; its average measurement is about 110 mm. in the

female. The *transverse diameter* extends from the middle of the brim on one side to the same point on the opposite side; its average measurement is about 135 mm. in the female. The *oblique diameter* extends from the iliopectineal eminence to the opposite sacro-iliac articulation; its average measurement is about 125 mm. in the female.

The *cavity* of the lesser pelvis is a short curved canal, considerably deeper behind than in front. It is bounded in front and below by the pubic rami and symphysis; above and behind, by the pelvic surfaces of the sacrum and coccyx; laterally by a smooth, quadrangular area of bone, formed by the inner surfaces of the body and superior ramus of the ischium and of the body of the ilium. It contains, in the recent subject, the sigmoid (pelvic) colon, rectum, urinary bladder, and some of the organs of generation. The rectum is placed at the back of the pelvis, in the curve of the sacrum and coccyx; the urinary bladder is in front, behind the pubic symphysis. In the female, the uterus and vagina lie between the rectum and the urinary bladder.

The *lower circumference* of the pelvis is very irregular; the space enclosed by it is named the *inferior aperture* or *outlet* (fig. 412), and is bounded behind

FIG. 412.—The diameters of the inferior aperture of the lessser pelvis (female).



by the apex of the coccyx, and laterally by the ischial tuberosities. These eminences are separated by three notches: one in front, the *pubic arch*, formed by the convergence of the inferior rami of the ischium and os pubis on either side. The other notches, one on either side, are formed by the sacrum and coccyx behind, the ischium in front, and the ilium above: they are called the *sciatic notches*; in the natural state they are converted into foramina by the sacrotuberous and sacrospinous ligaments. When these ligaments have been preserved, the inferior aperture of the pelvis is lozenge-shaped, and is bounded, in front, by the arcuate pubic ligament and the inferior rami of the ossa pubis et ischia; laterally, by the ischial tuberosities; behind, by the sacrotuberous ligaments and the tip of the coccyx.

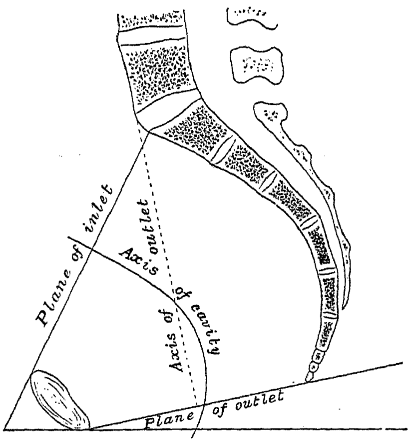
The *anteroposterior diameter* of the inferior aperture of the pelvis extends from the apex of the coccyx to the lower part of the pubic symphysis; its measurement is from 90 to 115 mm. in the female. It varies with the length of the coccyx, and is capable of increase or diminution, on account of the mobility of that bone. The *transverse diameter*, measured between the posterior parts of the ischial tuberosities, is about 115 mm. in the female.*

Axes (fig. 413).—The axis of the superior aperture, *i.e.* a line at right angles to the plane of the superior aperture through its centre, is directed downwards

* The measurements of the pelvis given above are fairly accurate, but different figures are given by various authors, no doubt mainly due to differences in the physique and stature of the population from whom the measurements have been taken.

and backwards, and if the line be prolonged it passes through the umbilicus above and the middle of the coccyx below. The axis of the inferior aperture is directed downwards and slightly backwards; if prolonged upwards it touches the base of the sacrum. The axis of the cavity—i.e. an axis at right angles to a series of planes between and including those of the superior and inferior apertures—is curved like the cavity itself: this curve is parallel to that of the sacrum and coccyx.

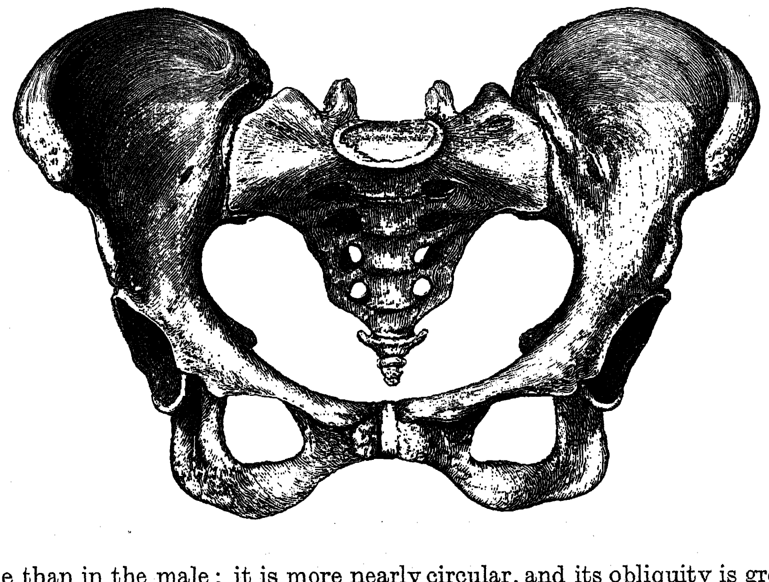
FIG. 413.—A median sagittal section through the pelvis.



Position of the pelvis (fig. 413).—In the erect posture, the pelvis is placed obliquely with regard to the trunk: the plane of the superior aperture forms with the horizontal plane an angle of from 50° to 60°, and that of the inferior aperture one of about 15°. The pelvic surface of the symphysis pubis looks upwards and backwards, the concavity of the sacrum and coccyx downwards and forwards. The position of the pelvis in the erect posture may be indicated by holding it so that the anterior superior iliac spines and the front of the top of the symphysis pubis are in the same vertical plane.

Differences between the male and female pelves (figs. 414, 415, 416, 417).—The female pelvis is distinguished from that of the male by its bones being more delicate and its depth less. The whole pelvis is less massive, and its muscular impressions are not so marked. The ilia are larger, their posterior borders are more rounded and less vertical. and the anterior iliac spines more widely separated; hence the greater lateral prominence of the hips. The superior aperture of the lesser pelvis is larger in the

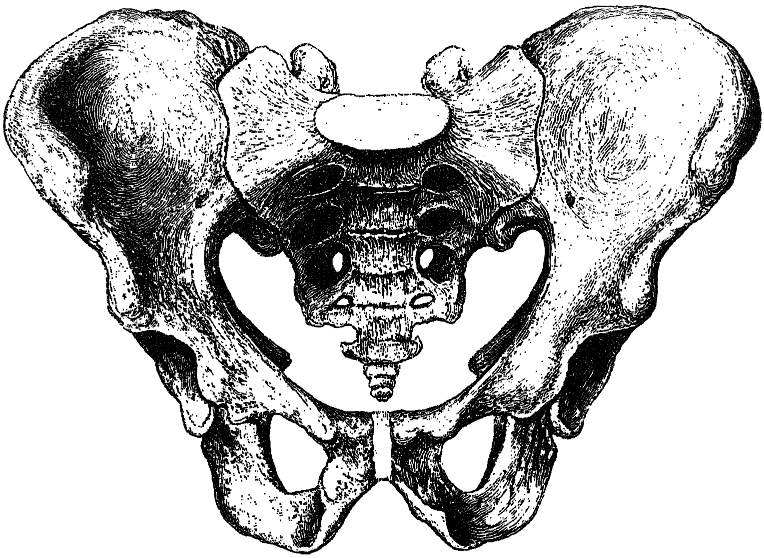
FIG. 414.—The female pelvis. Anterior aspect.
From a specimen in the museum of the Royal College of Surgeons of England.



female than in the male; it is more nearly circular, and its obliquity is greater. The cavity is shallower and wider; the sacrum is shorter, wider, and its upper part is less curved; the obturator foramina are triangular in shape and are smaller in size than in the male. The inferior aperture is larger, and the coccyx more movable. The pre-auricular sulci are more commonly present and better

marked. The sciatic notches are wider and shallower, and the spines of the ischia project less inwards. The acetabula are wider apart, smaller and look more distinctly forwards.* The ischial tuberosities are also wider apart,

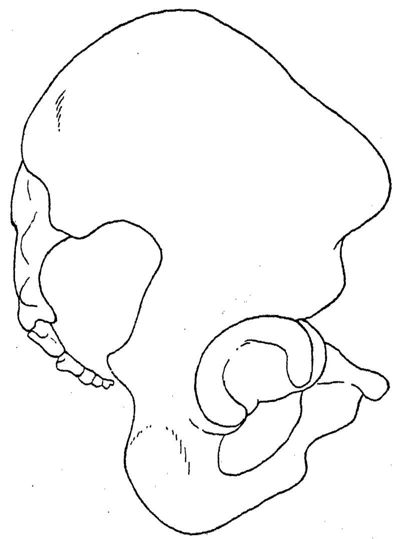
FIG. 415.—The male pelvis. Anterior aspect.



and are more everted. The depth of the pubic symphysis is less, and the pubic arch is wider and more rounded than in the male, where it is an angle rather than an arch. The auricular surfaces for articulation with the sacrum usually involve only two vertebræ, whereas in the male they extend over two and a half or three vertebræ.

FIG. 416.—Profile view of female pelvis.

FIG. 417.—Profile view of male pelvis.



The size of the pelvis varies not only in the two sexes, but also in different members of the same sex, and does not appear to be greatly influenced by the height of the individual. Women of short stature, as a rule, have broad

* Derry, *Journal of Anatomy and Physiology*, vol xliii.

pelves. Occasionally the pelvis is contracted in all its dimensions, and its diameters may be as much as 12·5 mm. less than the average, and this even in well-formed women of average height. The principal divergences, however, are found at the superior aperture, and affect the relation of the anteroposterior to the transverse diameter. Thus the superior aperture may be elliptical either in a transverse or an anteroposterior direction, the transverse diameter in the former, and the anteroposterior in the latter, greatly exceeding the other diameters ; in other instances it is almost circular.

In the *fœtus*, and for several years after birth, the pelvis is small in proportion to that of the adult, and the projection of the sacrovertebral angle less marked. The characteristic differences between the male and female pelves are distinctly indicated as early as the fourth month of fœtal life.

Applied Anatomy.—There is arrest of development in the bones of the pelvis in cases of extroversion of the bladder; the anterior part of the pelvic girdle is deficient, the superior rami of the pubic bones are imperfectly developed, and the symphysis is absent. The pubic bones are separated to the extent of from two to four inches, the superior rami shortened and directed forwards, and the obturator foramina diminished in size, narrowed, and turned outwards. The iliac bones are straightened out more than normal. The transverse curve of the sacrum is flattened out or even convex, and the vertical curve is straightened.*

Fractures of the pelvis are divided into those of the greater and those of the lesser pelvis. Fractures of the greater pelvis vary in extent; a small portion of the crest may be broken, or one of the spinous processes may be torn off, or the bone may be extensively comminuted. This latter accident is the result of some crushing violence, and may be complicated with fracture of the lesser pelvis. These cases may be accompanied by injury to the intestine or to the iliac vessels. A fracture of the lesser pelvis generally occurs through the superior ramus of the os pubis and the inferior ramus of the ischium, as these are the weakest parts of the bony ring, and may be caused either by crushing violence applied in an anteroposterior direction, when the fracture occurs from direct force, or by compression laterally, when the acetabula are pressed together and the bone gives way in the same place from indirect violence. Sometimes both sides of the pelvis are fractured, and it is in these cases that the contained viscera are likely to be injured: the urethra, the bladder, the rectum, the small intestines, the vagina, and even the uterus, have all been lacerated by displaced fragments. Fractures of the acetabulum are occasionally met with: either a portion of the rim may be broken off, or a fracture may take place through the bottom of the cavity, and the head of the femur be driven into the pelvic cavity. Separation of the Y-shaped cartilage at the bottom of the acetabulum may also occur in the young subject, splitting the bone into its three portions.

The coccyx is not infrequently displaced forwards to nearly a right angle with the sacrum by a kick or by a fall backwards. The condition is attended with great pain in walking and on making any expiratory effort, such as coughing, defæcation, etc., because the Coccygei and Levatores ani which form the pelvic diaphragm are attached to this bone. Such injuries often give rise to severe persistent pain, which is exceedingly intractable and difficult of cure. The condition is known as *coccygodynia*, and for its relief removal of the coccyx has been practised.

The pelvic bones often undergo important deformity in *rickets*, the effects of which in the adult woman may seriously interfere with child-bearing. The deformity is due mainly to the weight of the trunk, which presses on the sacrovertebral angle and greatly increases it, so that the anteroposterior diameter of the pelvis is diminished, and may measure as little as 40 mm., the entrance into the pelvis becoming reniform. In other cases all the pelvic bones yield, and a general diminution in all the diameters of the pelvis results, the pelvic entrance becoming triangular or asymmetrical. If the pubic symphysis be forced forwards, the rickety pelvis may even come to resemble closely the deformed pelvis of *osteomalacia* ; in this disease the weight of the trunk causes an increase in the sacrovertebral angle, and a lessening of the anteroposterior diameter of the superior aperture, and at the same time the pressure of the heads of the femora on the acetabula causes these cavities, with the adjacent bone, to be pushed upwards and backwards, so that the oblique diameters of the pelvis are also diminished, and the cavity of the pelvis assumes a triradiate shape, with the symphysis pubis pushed forwards.

The Femur

The **femur** (figs. 419 and 420), the longest and strongest bone in the skeleton, is cylindrical in the greater part of its extent. In the erect posture it is placed obliquely, being separated above from the bone of the opposite limb by an interval which corresponds to the breadth of the pelvis, but inclines gradually

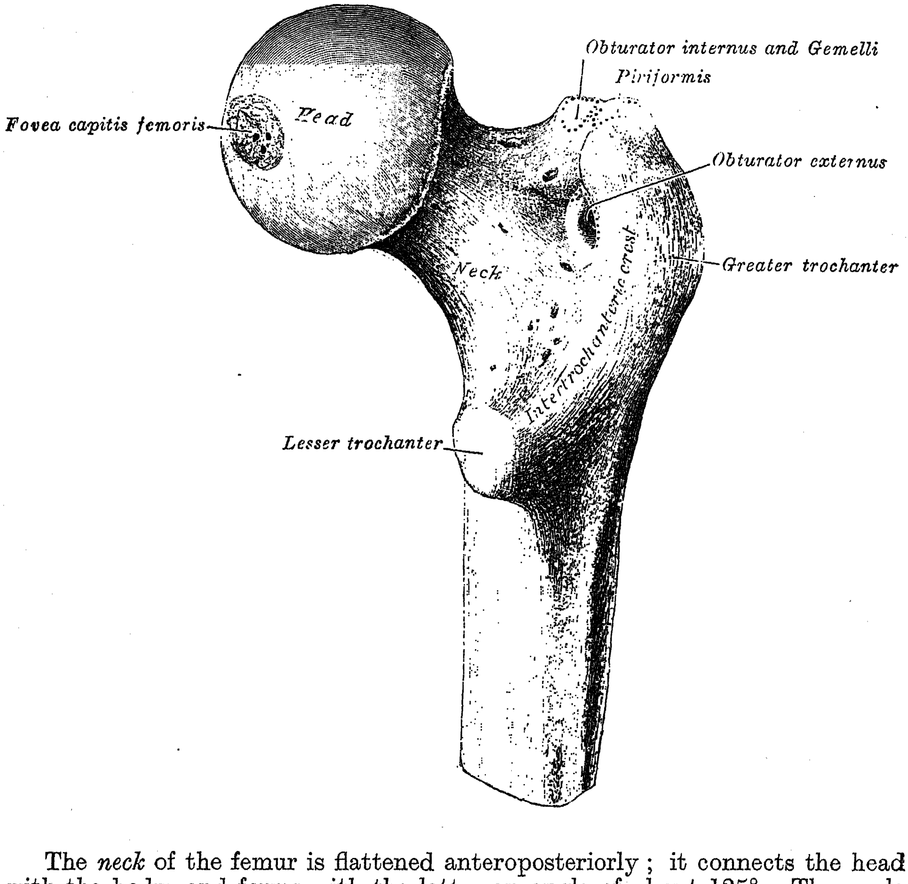
* Wood. Heath's *Dictionary of Practical Surgery*.

downwards and medialwards, so as to bring the knee-joint near the line of gravity of the body. The degree of this inclination varies in different persons, and is greater in the female than in the male, on account of the greater breadth of the pelvis. The femur has a body and two ends.

The **upper end** of the femur (fig. 418) comprises a head, a neck, a greater and a lesser trochanter.

The *head* forms rather more than a hemisphere ; it articulates with the acetabulum of the hip-bone, and is directed upwards, medialwards, and a little forwards. Its surface is smooth, except at an ovoid depression, the *fovea capitis femoris,* which is situated a little below and behind the centre of the head and gives attachment to the ligamentum teres of the hip-joint.

FIG. 418.—The upper extremity of the right femur. From behind and above.



The *neck* of the femur is flattened anteroposteriorly ; it connects the head with the body, and forms with the latter an angle of about 125°. The angle decreases during the period of growth, but after full growth has been attained it does not usually undergo any change ; in the female, in consequence of the greater width of the pelvis, it is less than in the male. In addition to projecting upwards and medialwards from the body of the femur, the neck projects somewhat forwards ; the amount of this forward projection is extremely variable, but on an average is from 12° to 14°.

The neck is contracted in the middle, and broader laterally than medially. The vertical diameter of the lateral half is increased by the obliquity of the lower edge, which slopes downwards to join the body at the level of the lesser trochanter ; the medial half is smaller, and of a more cylindrical shape. The *anterior surface* of the neck is perforated by numerous foramina for vessels. Along the upper part, and encroaching on the line of junction of this surface with the head is a shallow, rough groove, best marked in elderly subjects ; this groove lodges the orbicular fibres of the capsule of the hip-joint. The *posterior*

surface is more concave than the anterior, and usually exhibits a shallow, oblique groove for the tendon of the Obturator externus; the articular capsule of the hip-joint is attached to the posterior surface of the neck about 1 cm. above the intertrochanteric crest. The *superior border*, short and thick, ends laterally at the greater trochanter, and is perforated by large foramina. The *inferior border*, long and narrow, curves a little backwards, and ends at the lesser trochanter.

The *greater trochanter* of the femur is a large, quadrangular eminence, situated at the junction of the neck and the upper part of the body. It is directed upwards, lateralwards, and slightly backwards, and its superior border is on a level with the centre of the head of the bone. The *lateral surface*, quadrilateral in form, is broad, rough, convex, and marked by an oblique ridge, which extends from the posterosuperior to the antero-inferior angle and serves for the insertion of the tendon of the Glutæus medius; above and in front of this ridge is a triangular surface which is separated from the tendon by a bursa. Below and behind the oblique ridge is a smooth surface, over which the tendon of the Glutæus maximus plays, a bursa being interposed. The *medial surface* is of much less extent than the lateral; at its lower part is a deep depression, the *trochanteric fossa*, for the insertion of the tendon of the Obturator externus; above and slightly in front of this fossa is an impression for the insertion of the Obturator internus and Gemelli. The *superior border* is free; it is thick and curved, and near its centre is an impression for the insertion of the Piriformis. The *inferior border* corresponds to the line of junction of the trochanter with the lateral surface of the body of the femur; it is marked by a rough, slightly curved ridge, which gives origin to the upper part of the Vastus lateralis. The

Fig. 419.—The right femur. Anterior aspect.

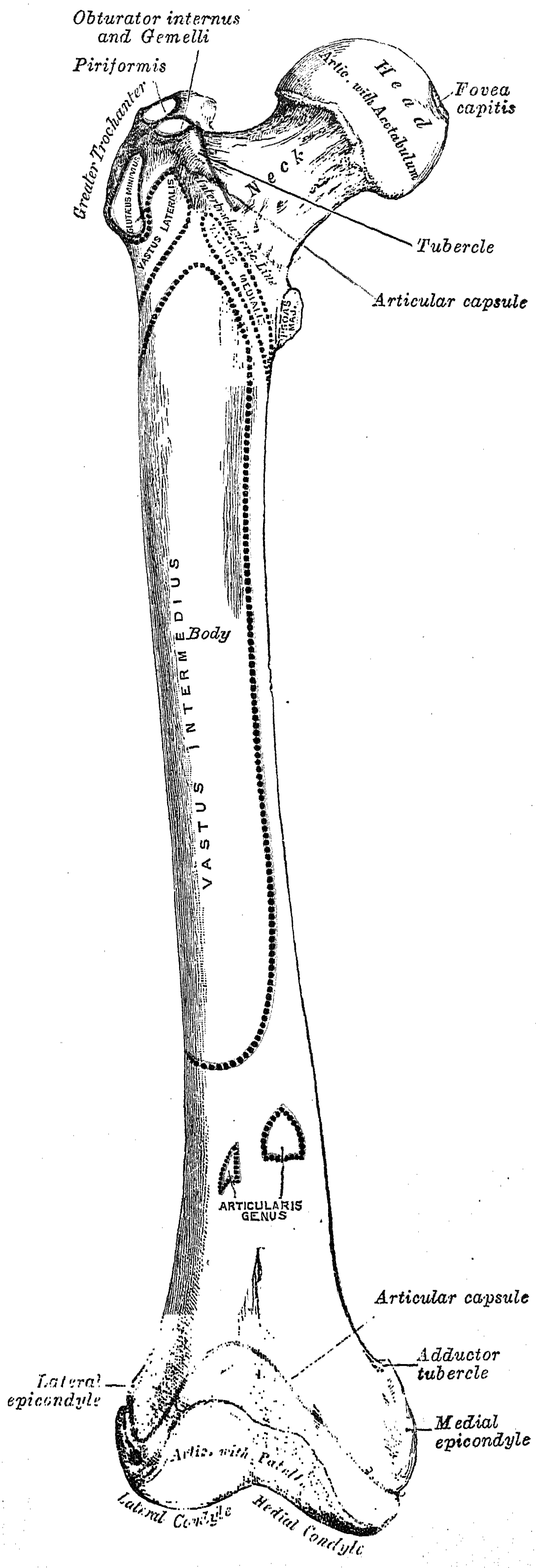
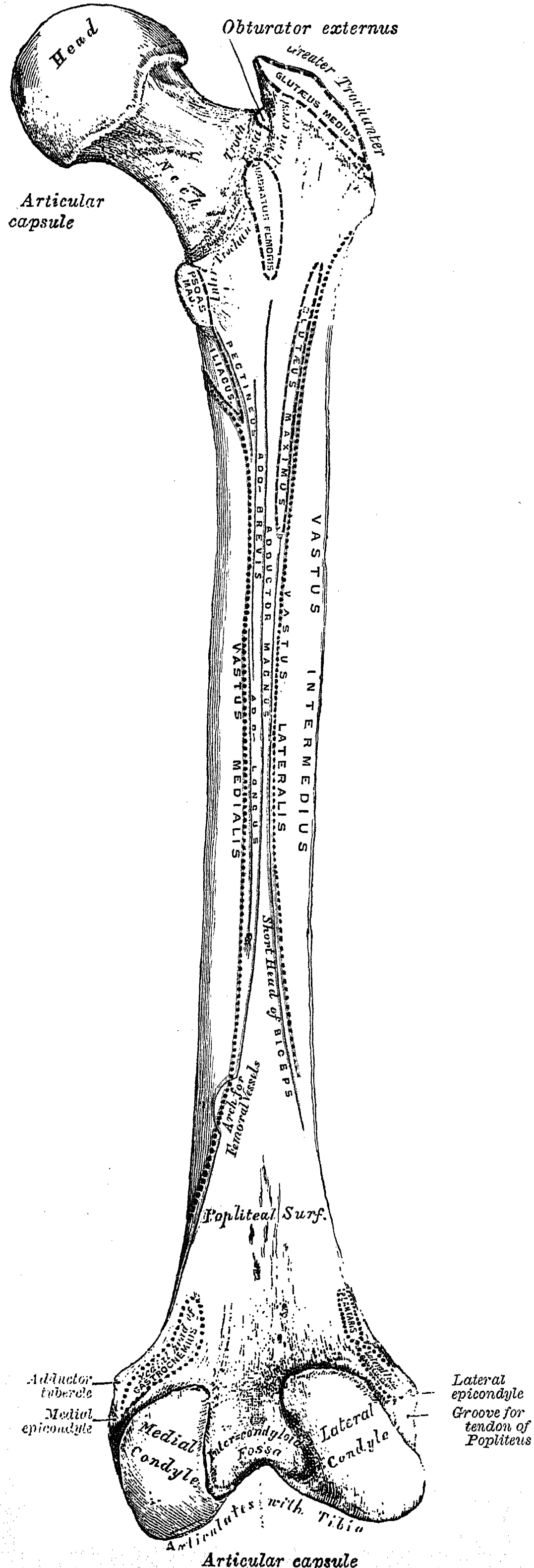


FIG. 420.—The right femur. Posterior aspect.



anterior surface is quadrilateral in shape. The tendon of the Glutæus minimus is attached to a prominent ridge on the lateral part of this surface, and is separated from the medial part by a synovial bursa. The *posterior border* is a projecting rounded edge, which bounds the back of the trochanteric fossa, and forms the upper part of the intertrochanteric crest.

The *lesser trochanter* of the femur is a conical eminence which projects from the body at its junction with the lower and posterior part of the neck. From it three borders extend; two of these are directed upwards—a *medial* continuous with the lower border of the neck; a *lateral* with the intertrochanteric crest; the third or *inferior* is continuous with the middle division of the linea aspera. The *summit* of the trochanter is rough, and gives insertion to the tendon of the Psoas major.

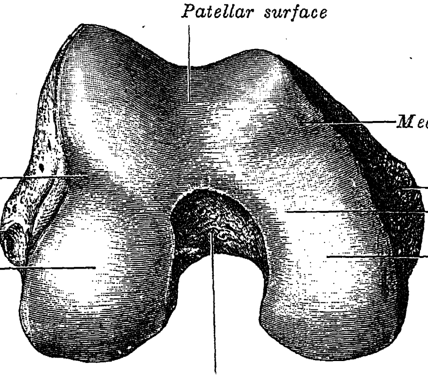
A prominence, of variable size, occurs at the junction of the upper part of the front of the neck with the greater trochanter, and is called the *tubercle* of the femur. Running downwards and medialwards from it is the *intertrochanteric line*; this line winds spirally round the medial side of the body of the bone, in front of the lesser trochanter, and ends about 5 cm. below this eminence in the linea aspera. Its upper half is rough, and affords attachment to the lateral part of the iliofemoral ligament of the hip-joint; to its lower half, which is less prominent, the medial part of the iliofemoral ligament and the pubocapsular ligament are attached. On the posterior surface a prominent ridge, the *intertrochanteric crest*, runs obliquely downwards and medialwards from the summit of the greater trochanter to the lesser trochanter; its upper half forms the posterior border of the greater trochanter. A slight ridge, the *linea quadrata*, is sometimes seen commencing about the middle of this crest,

and running vertically downwards for about 5 cm. along the triangular surface between the lateral and intermediate ridges of the linea aspera; it gives attachment to the Quadratus femoris and a few fibres of the Adductor magnus; as a rule, there is merely a slight thickening about the middle of the intertrochanteric crest, marking the attachment of the upper part of the Quadratus femoris.

The **body** or **shaft** of the femur, almost cylindrical in form, is a little broader above than in the centre, broadest and somewhat flattened from before backwards below. It is slightly arched, so as to be concave behind, where it is strengthened by a prominent longitudinal crest, the *linea aspera*. It has three borders and three surfaces. Of the borders, one, the linea aspera, is posterior, one is medial, and the other, lateral.

The *linea aspera* (fig. 420) is a longitudinal crest, on the middle third of the bone; it has a medial and a lateral lip, and a narrow, rough, intermediate line. Three ridges, lateral, intermediate and medial, run upwards from the linea aspera. The lateral ridge is very rough, and ascends to the base of the greater trochanter; it is termed the *glutæal tuberosity*, and gives insertion to

Fig. 421.—The lower end of the right femur. Inferior aspect.



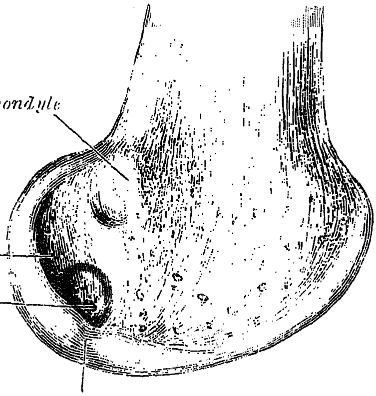
a part of the Glutæus maximus: its upper part is often elongated into a roughened crest, on which a rounded tubercle, the *third trochanter*, is occasionally developed. The intermediate ridge or *pectineal line* is continued to the base of the lesser trochanter and gives insertion to the Pectineus. The medial ridge or *spiral line* is continuous with the intertrochanteric line. The lips of the linea aspera diverge below and are prolonged as two epicondylar ridges which form the sides of a triangular area named the *popliteal surface*. The lateral epicondylar ridge is the more prominent, and descends to the lateral epicondyle. The medial epicondylar ridge is indistinct above where it is crossed by the femoral artery; it ends below, at the medial epicondyle, in the *adductor tubercle* which affords insertion to the tendon of the Adductor magnus. In about 80 per cent. of specimens a rounded tubercle is present on the lower part of the popliteal surface, just above the medial condyle; to this tubercle the upper part of the medial head of the Gastrocnemius is attached.*

From the medial lip of the linea aspera and its prolongations above and below, the Vastus medialis arises; and from the lateral lip and its upward prolongation, the Vastus lateralis takes origin. The Adductor magnus is inserted into the linea aspera, and to its lateral prolongation above, and its medial prolongation below. Between the Vastus lateralis and the Adductor magnus the Glutæus maximus is inserted above, and the short head of the Biceps femoris takes origin below. Between the Adductor magnus and the Vastus medialis four muscles are inserted: the Iliacus and the Pectineus above; the Adductor brevis and the Adductor longus below. Near the middle

* F. G. Parsons, *Journal of Anatomy and Physiology*, vol. xlviii., and J. S. B. Stopford, *Journal of Anatomy and Physiology*, vol. xlix.

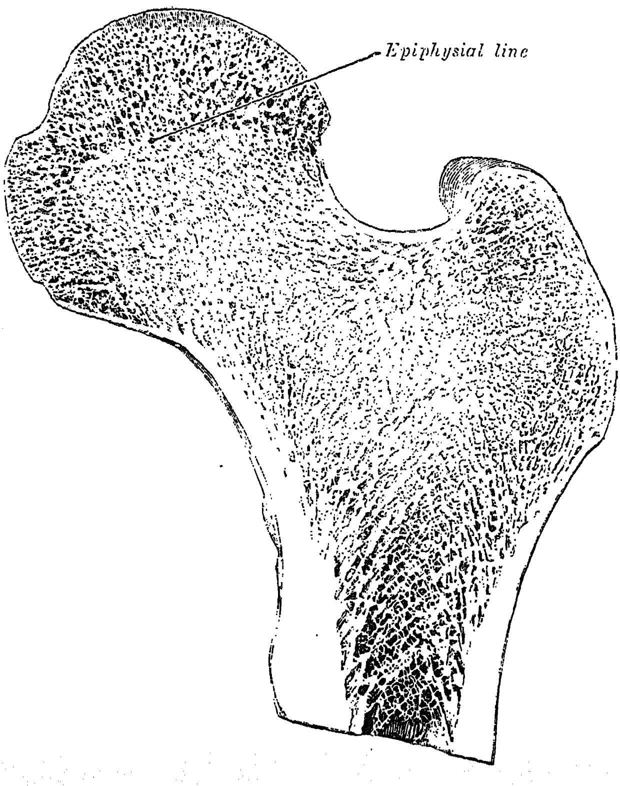
of the linea aspera is the orifice of the canal for the nutrient artery, which is directed obliquely upwards.

FIG. 422.—The lower end of the right femur. Lateral aspect.



The *lateral* and *medial borders* of the femur are only slightly marked ; the lateral extends from the antero-inferior angle of the greater trochanter to the front of the lateral condyle ; the medial from the intertrochanteric line, at the level of the lesser trochanter, to the front of the medial condyle.

FIG. 423.—A longitudinal section through the head and neck of the femur.

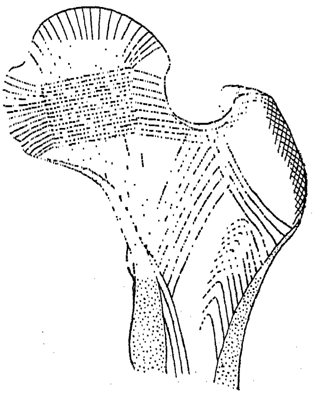


The *anterior surface* of the femur is between the lateral and medial borders; it is smooth, convex, broader above and below than in the middle. The Vastus

intermedius arises from its upper three-fourths, and from the upper part of its lower one-fourth the Articularis genus takes origin. The *lateral surface* is between the lateral border and the linea aspera ; it is continuous above with the lateral surface of the greater trochanter, below with that of the lateral condyle : the Vastus intermedius arises from its upper three-fourths. The *medial surface* is between the medial border and the linea aspera ; it is continuous above with the lower border of the neck, below with the medial side of the medial condyle ; it is covered by the Vastus medialis.

The **lower end** of the femur (figs. 421, 422) is larger than the upper, and consists of two oblong eminences, known as the *condyles* ; in front, these are but slightly prominent, and are separated by a smooth shallow articular depression called the *patellar surface* ; behind, they project considerably, and are separated by a deep notch, the *intercondyloid fossa.* The *lateral condyle* is the more prominent anteriorly, and is the broader both in its anteroposterior and transverse diameters. The *medial condyle* projects to a lower level than the lateral, when the femur is held with its body perpendicular ; when, however, the bone is in its natural oblique position the lower surfaces of the two condyles lie in the same horizontal plane. The condyles are not quite parallel with one another ; the long axis of the lateral is almost directly anteroposterior, but that of the medial runs backwards and medialwards. Their opposed surfaces are small, rough, and concave, and form the walls of the intercondyloid fossa ; this fossa is limited above by a ridge, the *intercondyloid line,* and below by the central part of the posterior margin of the patellar surface. The posterior cruciate ligament of the knee-joint is attached to the lower and front part of the medial wall of the fossa, and the anterior cruciate ligament to the upper and posterior part of its lateral wall. Each condyle is surmounted by an elevation, the epicondyle. The *medial epicondyle* is a large convex eminence to which the tibial collateral ligament of the knee-joint is attached. At its upper part is the adductor tubercle, already referred to, and behind it is a rough impression which gives origin to a large part of the medial head of the Gastrocnemius. The *lateral epicondyle* (fig. 422), smaller and less prominent than the medial, gives attachment to the fibular collateral ligament of the knee-joint. Directly below it is a small depression from which a deep, oblique groove curves upwards and backwards to the posterior end of the condyle. This groove is separated from the articular surface of the condyle by a rounded lip, across the anterior part of which a vertical, shallow groove descends from the depression. In the recent state these grooves are covered with cartilage. The Popliteus arises from the depression below the epicondyle ; its tendon lies in the oblique groove when the knee is acutely flexed, and in the vertical groove when the knee is extended. Above and behind the lateral epicondyle is an area for the origin of the lateral head of the Gastrocnemius, above and medial to which the Plantaris arises.

FIG. 424.—A scheme showing the disposition of the principal cancellous lamellæ in the upper end of the femur.



The *articular surface* of the lower end of the femur occupies the anterior, inferior, and posterior surfaces of the condyles. Its front part articulates with the patella, and is named the *patellar surface* ; it presents a median groove between two convexities, the lateral of which is broader, more prominent, and ascends farther than the medial. The lower and posterior parts of the articular surface constitute the *tibial surfaces* for articulation with the corresponding condyles of the tibia and the menisci of the knee-joint. The tibial surfaces are separated from one another by the intercondyloid fossa, and from the patellar surface by two faint grooves which extend obliquely across the condyles. The lateral groove is the better marked ; it runs lateralwards and slightly forwards from the front part of the intercondyloid fossa, and expands to form a triangular depression which rests upon the anterior portion of the lateral meniscus when the knee-joint is fully

extended. The medial groove is less distinct than the lateral, and exists only on the medial part of the condyle; it receives the anterior edge of the medial meniscus when the knee-joint is extended. Where this groove ceases laterally the patellar surface is continued backwards on the medial condyle as a semilunar area adjoining the anterior part of the intercondyloid fossa; this semilunar area articulates with the medial vertical facet of the patella in forced flexion of the knee-joint. The tibial surfaces of the condyles are convex from side to side and from before backwards. Each presents a double curve, its posterior segment being an arc of a circle, its anterior, part of a cycloid.*

FIG. 425.—An oblique section through the upper end of the left femur showing the calcar femorale.

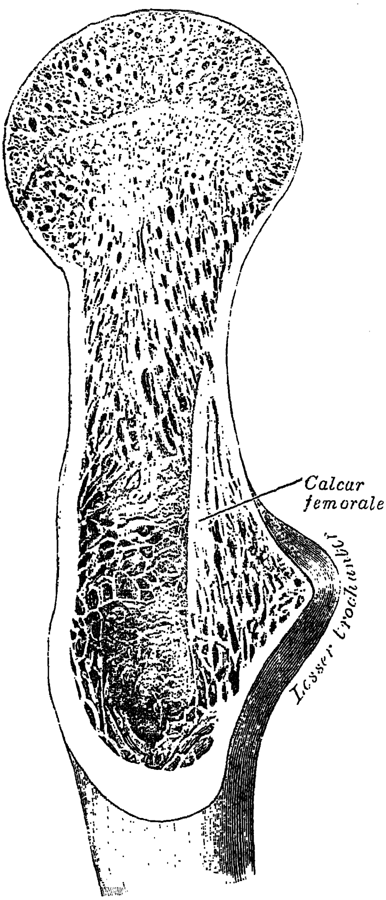
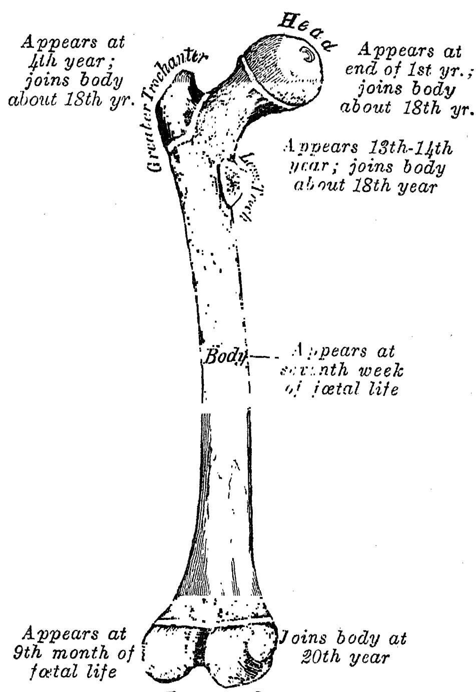


FIG. 426.—A plan of the ossification of the femur. From five centres.



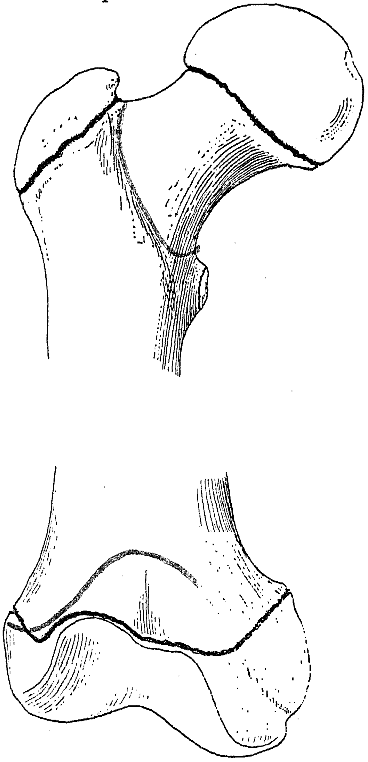
Structure.—The body of the femur is a cylinder of compact bone, hollowed by a large medullary canal. The wall of the cylinder is thick in the middle one-third of the body, where the bone is narrowest and the medullary canal best formed; but above and below this the wall becomes thinner, while the medullary canal is gradually filled up by spongy substance, so that the upper and lower ends of the body, and the articular extremities more especially, consist of spongy substance, invested by a thin compact layer.

The cancelli in the ends of the femur are disposed along the lines of greatest pressure and tension. In the upper end (figs. 423, 424) the chief lamellæ are arranged in the following manner. A series of bony planes at right angles to the articular surface of the head converge to a central dense wedge; this wedge is supported

* A *cycloid* is a curve traced by a point in the circumference of a wheel when the wheel is rolled along in a straight line.

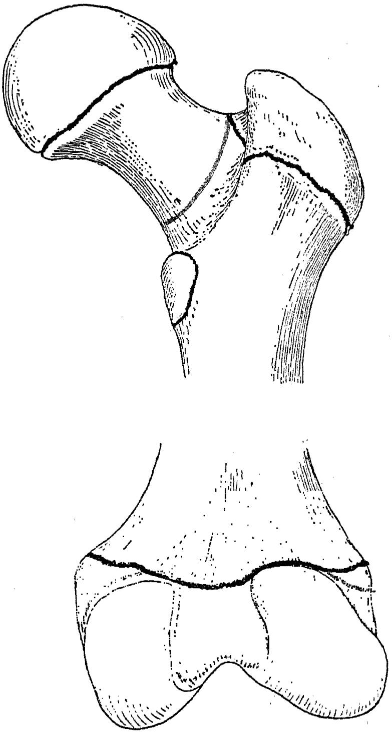
by strong lamellæ which extend to the sides of the neck and are specially marked along its upper and lower borders. Any force therefore applied to the head of the femur is transmitted directly to the central wedge and thence to the junction of the neck with the body. This junction is specially strengthened by a series of dense lamellæ which extend from the lesser trochanter to the lateral end of the superior border of the neck; this arrangement will obviously oppose considerable resistance to either tensile or shearing force. A smaller bar stretching across the junction of the greater trochanter with the neck and body resists the shearing force of the muscles attached to this prominence. These two bars, one at the junction of body and neck, the other at the junction of body and greater trochanter, form the upper layers of a series of arches which extend across between the sides

Fig. 427.—The epiphysial lines of the right femur in a young adult. Anterior aspect.



The lines of attachment of the articular capsules are in blue.

Fig. 428.—The epiphysial lines of the right femur in a young adult. Posterior aspect.



The lines of attachment of the articular capsules are in blue.

of the body and transmit to the body forces applied to the upper end of the bone. In the spongy substance of the neck is a thin vertical plate of bone, the *calcar femorale* (fig. 425), which springs from the compact wall of the body in the region of the linea aspera. Medially it is attached to the inner surface of the posterior wall of the neck of the bone; laterally it continues the plane of the posterior wall of the neck into the greater trochanter, where it shades off into the general spongy substance. It is thus situated in a plane anterior to the intertrochanteric crest and to the base of the lesser trochanter.

In the lower end, the cancelli spring on all sides from the inner surface of the cylinder, and descend in a direction perpendicular to the articular surface, the cancelli being strongest and having a more accurately perpendicular course above the condyles. In addition to this, there are horizontal planes of cancellous tissue, so that the spongy substance in this situation is mapped out into a series of cubical compartments.

Ossification (figs. 426, 427, 428).—The femur is ossified from five centres: one each for the body, head, greater trochanter, lesser trochanter, and lower end

Except the clavicle, it is the first of the long bones to show traces of ossification. Ossification begins in the middle of the body in the seventh week of fœtal life, and extends upwards and downwards. The secondary centres appear as follows: in the lower end, during the ninth month of fœtal life (from this centre the condyles and epicondyles are formed); in the head at the end of the first year; in the greater trochanter during the fourth year; and in the lesser trochanter between the thirteenth and fourteenth years. The epiphyses, derived from the secondary centres, fuse independently with the body after puberty; the lesser trochanter joins first, then the greater, then the head, and, lastly, the lower end which is not united until the twentieth year.

Applied Anatomy.—The lower end of the femur is the only epiphysis in which ossification has commenced at the time of birth. The presence of this centre of ossification is, therefore, a proof, in a new-born child found dead, that the child has arrived at the full period of uterogestation, and is always relied upon in medico-legal investigations. The position of the epiphysial plate should be carefully noted. It is on a level with the adductor tubercle, and the epiphysis does not, therefore, form the whole of the synovial covered portion of the lower end of the bone. It is essential to bear this point in mind in performing excision of the knee, since growth in length of the femur takes place chiefly from the lower epiphysis, and any interference with the epiphysial cartilage in a young child would involve such ultimate shortening of the limb, from want of growth, as to render the limb almost useless. Separation of the lower epiphysis may take place up to the age of twenty, at which time it becomes completely joined to the body of the bone; but, as a matter of fact, few cases occur after the age of sixteen or seventeen. The epiphysis of the head of the femur is the seat of origin, in a large number of cases, of tuberculous disease of the hip-joint. In the majority of cases the disease begins in the highly vascular and growing tissue at the end of the body in the neighbourhood of the epiphysial cartilage, and extends into the joint. The epiphysis for the head is entirely intracapsular.

Fractures of the femur are divided, like those of the other long bones, into fractures of the upper end; of the body; and of the lower end. The fractures of the upper end may be classified into (1) fracture of the neck; (2) fracture at the junction of the neck with the greater trochanter; (3) fracture of the greater trochanter; and (4) separation of the epiphysis, either of the head or of the greater trochanter. The first of these, fracture of the neck, is usually termed *intracapsular* fracture, but this is scarcely a correct designation, as, owing to the attachment of the articular capsule, the fracture is partly within and partly without the capsule when the fracture occurs at the lower part of the neck. It generally takes place in old people, principally women, and usually from a very slight degree of indirect violence. Probably the main cause of its occurrence in old people is the senile degenerative change which takes place in the bone. Merkel believes that it is mainly due to the absorption of the calcar femorale. As a rule the fragments become united by fibrous tissue, but frequently no union takes place, and the opposed surfaces become smooth and eburnated.

Fractures at the junction of the neck with the greater trochanter are usually termed *extracapsular*, but this designation is also incorrect, as the fracture is partly within the capsule, which is attached in front to the intertrochanteric line below the line of fracture. These fractures are produced by direct violence to the greater trochanter, as from a fall laterally on the hip. From the manner in which the accident is caused the neck of the bone is driven into the trochanter, where it may remain impacted or the trochanter may be split into two or more fragments, disimpaction resulting.

Fractures of the body may occur at any part, but the most usual situation is at or near the centre of the bone. Fractures of the upper third of the body are almost always the result of indirect violence, while those of the lower third are the result, for the most part, of direct violence. Fractures of the body are generally oblique, but they may be transverse, longitudinal, or spiral. The transverse fracture occurs most frequently in children. The fractures of the lower end of the femur include transverse fracture above the condyles, the most common; and this may be complicated by a vertical fracture between the condyles, constituting the T-shaped fracture. In these cases the popliteal artery is in danger of being wounded. Oblique fracture separating either the medial or lateral condyle, and a longitudinal incomplete fracture between the condyles, may also take place.

When there is a possibility of a fracture of the femur resulting in shortening of the bone, treatment should be carried out in the abducted position, so that the tilting of the pelvis to counteract the abduction may produce lengthening. The replacement of fractures of the lower one-third is facilitated by flexing the knee and so relaxing the gastrocnemius and the hamstrings.

The femur is exposed, with least injury to the vascular and nervous supply of the muscles, through an incision in the line of the lateral intermuscular septum.

The femur and the other long bones of the leg are frequently the seat of acute osteomyelitis in children. This is no doubt due to their greater exposure to injury, which is often the exciting cause of this disease. Necrosis of portions of the diaphysis

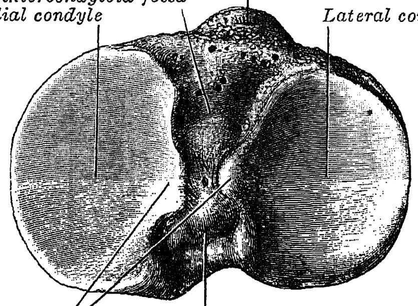
frequently ensue, especially in the region of the popliteal surface of the femur, and the disease may continue for years, great trouble being experienced with discharging sinuses which periodically close and reopen to allow of the exit of pieces of dead bone.

Tumours are not infrequently found growing from the femur: the most common forms being sarcoma, which may grow either from the periosteum or from the medullary tissue within the interior of the bone, and exostosis, which commonly originates in the neighbourhood of the epiphysial cartilage of the lower end. The region of the lower epiphysial line is by far the commonest seat for all these tumours, and it should be noted that the lower epiphysis has the longest period of active growth, and that these tumours usually appear towards the end of the period of active growth of the bone.

The Tibia

The **tibia** (figs. 430, 431) is situated at the medial side of the leg, and, excepting the femur, is the longest bone of the skeleton. It is prismoid in form, expanded above, where it enters into the formation of the knee-joint, contracted in the lower one-third, and again enlarged, but to a lesser extent, below. It has a body and two ends.

Fig. 429.—The upper surface of the right tibia.



The **upper end** of the tibia (fig. 429) is expanded into two eminences, the *medial and lateral condyles*, the superior surfaces of which form the medial and lateral articular surfaces. The medial articular surface, oval in shape, is slightly concave from side to side, and from before backwards; the lateral, nearly circular, is concave from side to side, but slightly convex from before backwards, especially at its posterior part where it is prolonged on to the posterior surface for a short distance. The central portions of the medial and lateral articular surfaces articulate with the condyles of the femur, while their peripheral portions support the menisci of the knee-joint, which here intervene between the tibia and the femoral condyles. Between the articular surfaces, and nearer the posterior than the anterior part of the bone, is the *intercondyloid eminence* (tibial spine), surmounted by two prominent tubercles, on the sides of which the articular surfaces are prolonged; in front of and behind the intercondyloid eminence are rough depressions, the *anterior and posterior intercondyloid fossæ*, for the attachment of the cruciate ligaments and the menisci of the knee-joint. The anterior surfaces of the condyles are continuous with one another, forming a large, triangular, somewhat flattened area; this area is perforated by foramina for vessels, and ends below in an oblong elevation, the *tuberosity* of the tibia, which gives attachment to the ligamentum patellæ; a bursa intervenes between the deep surface of the ligament and the part of the bone immediately above the tuberosity. The *medial condyle* is grooved posteriorly, for the insertion of the tendon of the Semimembranosus; its medial surface, convex, rough and prominent, gives attachment to the posterior part of the tibial collateral ligament of the knee-joint. The *lateral condyle* presents

posteriorly a flat, nearly circular, articular facet, directed downwards, backwards, and lateralwards, for articulation with the head of the fibula. Its lateral surface is convex, rough and prominent in front: on it is an eminence, situated on a level with the articular facet for the fibula, for the attachment of the iliotibial tract or band of the fascia lata. Just below this eminence a slip from the tendon of the Biceps femoris is inserted, and a small part of the Extensor digitorum longus takes origin.

The **body or shaft** of the tibia has three crests or margins, and three surfaces.

The *anterior crest* or *shin*, the most prominent, begins above at the tuberosity, and ends below at the anterior margin of the medial malleolus. It is sinuous and prominent in its upper two-thirds, but smooth and rounded below; it gives attachment to the deep fascia of the leg.

The *medial margin* is smooth and rounded above and below, but more prominent in the centre; it begins at the posterior part of the medial condyle, and ends at the posterior border of the medial malleolus; its upper part gives attachment to the tibial collateral ligament of the knee-joint to the extent of about 5 cm., and insertion to some fibres of the Popliteus; from its middle one-third some fibres of the Soleus and Flexor digitorum longus take origin.

The *interosseous crest* gives attachment to the crural interosseous membrane (fig. 434), and is most distinct in the middle one-third of the bone; it begins above in front of the fibular articular facet, and bifurcates below to form the sides of a triangular rough depression, the *fibular notch*, for the attachment of the interosseous ligament connecting the tibia and fibula.

The *medial surface* is smooth and convex, and is broader above than below. Its upper one-third is covered by an aponeurosis derived from the tendon of the Sartorius, and by the tendons of the Gracilis and Semitendinosus; all three are inserted into this part of the bone. The rest of the surface is subcutaneous.

The *lateral surface* is narrower than the medial; on its upper two-thirds is a shallow groove for the origin of the Tibialis anterior; its lower one-third is smooth, convex, curves gradually forwards to the anterior aspect of the bone, and is covered by the tendons of the Tibialis anterior, Extensor hallucis longus, and Extensor digitorum longus, arranged in this order from the medial side.

At the upper part of the *posterior surface* (fig. 431) is a prominent ridge, the *popliteal line*, which descends obliquely from the fibular articular facet to the medial border, near the junction of the upper with the middle one-third; the fascia covering the Popliteus muscle is attached to this line, and parts of the Soleus, Flexor digitorum longus, and Tibialis posterior take origin from it. Above the line is a triangular area, into the greater part of which the Popliteus is inserted; immediately below the line is the orifice of the nutrient canal, which is large and directed obliquely downwards. The middle one-third of the posterior surface is divided into two areas by a vertical ridge which begins at the popliteal line and is usually well marked above, but indistinct below; the medial and broader area gives origin to the Flexor digitorum longus, the lateral and narrower to a part of the Tibialis posterior. The lower part of the posterior surface is smooth and covered by the Tibialis posterior, Flexor digitorum longus, and Flexor hallucis longus.

The **lower end** of the tibia is prolonged downwards on its medial side as a strong process, the *medial malleolus*. The *inferior articular surface* is quadrilateral, and articulates with the talus. It is broader in front than behind, concave from before backwards, and near the middle is traversed in this direction by a slight elevation. It is continuous with the articular surface on the lateral side of the medial malleolus. The *anterior surface* is smooth and rounded above, and covered by the tendons of the Extensor muscles; at its lower margin is a furrow for the attachment of the articular capsule of the ankle-joint. The lateral part of the *posterior surface* is traversed by a shallow groove, directed obliquely downwards and medialwards, in which the tendon of the Flexor hallucis longus lies. On the *lateral surface* is a triangular rough depression, the *fibular notch*, for the attachment of the interosseous ligament connecting the tibia with the fibula; in the recent state, the lower border of this notch is occasionally covered with cartilage, and articulates with the fibula. The fibular notch is bounded by two prominent borders, continuous above with the interosseous crest; their lower parts afford attachment to the anterior and posterior ligaments of the lateral malleolus.

Fig. 430.—The bones of the right leg. Anterior aspect.

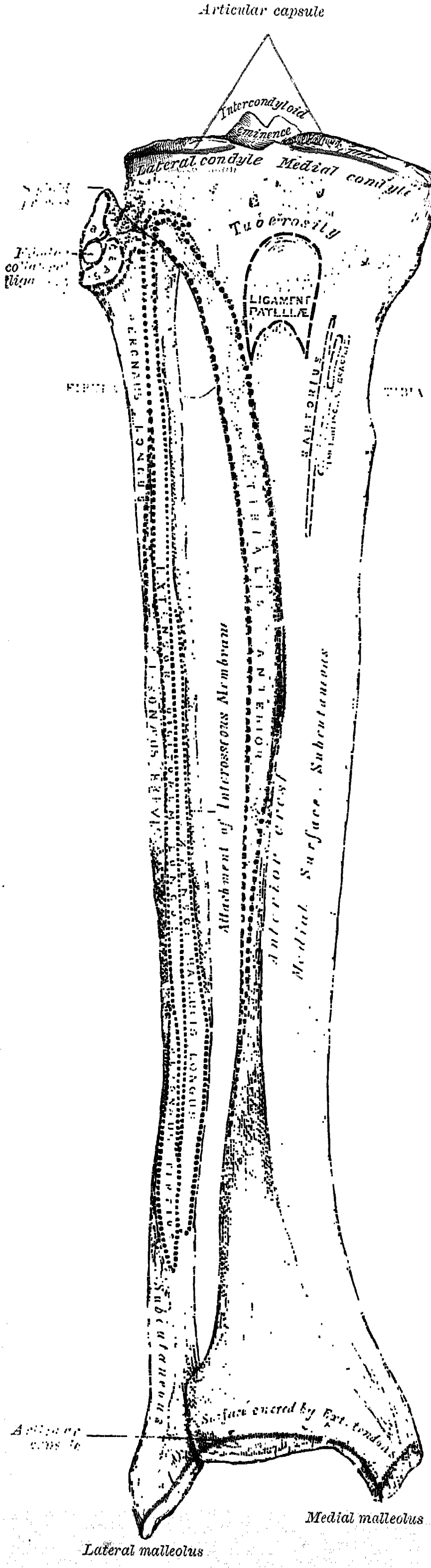
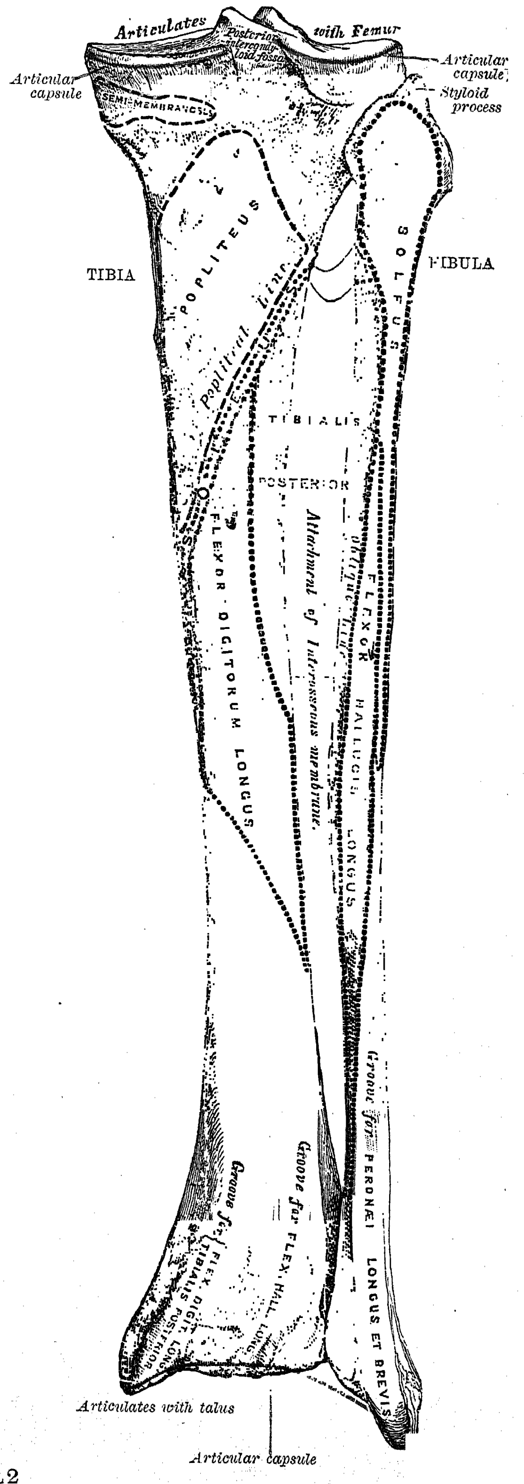


Fig. 431.—The bones of the right leg. Posterior aspect.



The *medial malleolus* is a strong pyramidal process, flattened from side to side. Its *medial surface* is convex and subcutaneous; its *lateral or articular surface*, smooth and slightly concave, articulates with the talus; its *anterior border* is rough, for the attachment of the anterior fibres of the deltoid ligament of the ankle-joint: on its *posterior border* is a broad groove, the *malleolar sulcus*, directed obliquely downwards and medialwards, and occasionally double; it lodges the tendons of the Tibialis posterior and Flexor digitorum longus. The *lower border* of the malleolus is marked posteriorly by a depression, for the attachment of the deltoid ligament of the ankle-joint.

FIG. 432.—A plan of the ossification of the tibia. From three centres.

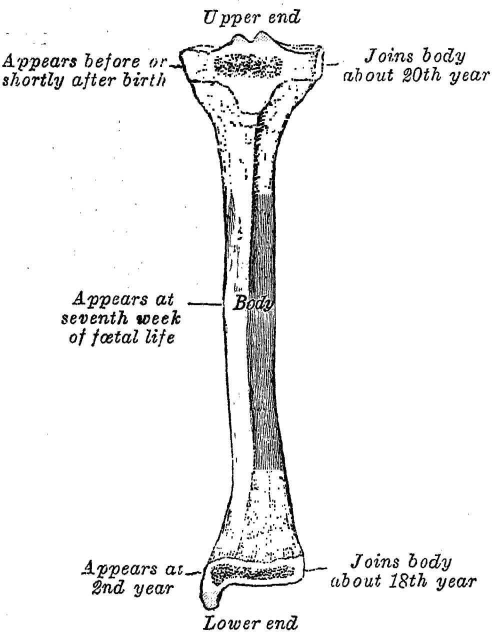
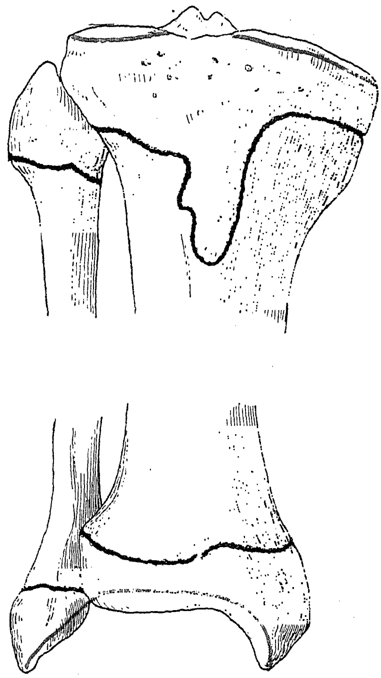


FIG. 433.—The epiphysial lines of the right tibia and fibula in a young adult. Anterior aspect.



The lines of attachment of the articular capsules are in blue.

Structure.—The structure of the tibia is like that of the other long bones. The compact wall of the body is thickest at the junction of the middle with the lower one-third of the bone.

Ossification.—The tibia is ossified from three centres (figs. 432, 433): one for the body and one for either end. Ossification begins in the middle of the body about the seventh week of fœtal life. The centre for the upper end appears before or shortly after birth, and from it a thin tongue-shaped process extends downwards in front, to form the tuberosity (fig. 433); the centre for the lower end appears in the second year. The lower end joins the body about the eighteenth year; the upper about the twentieth year. Two additional centres occasionally exist, one for the tongue-shaped process which forms the tuberosity, and one for the medial malleolus.

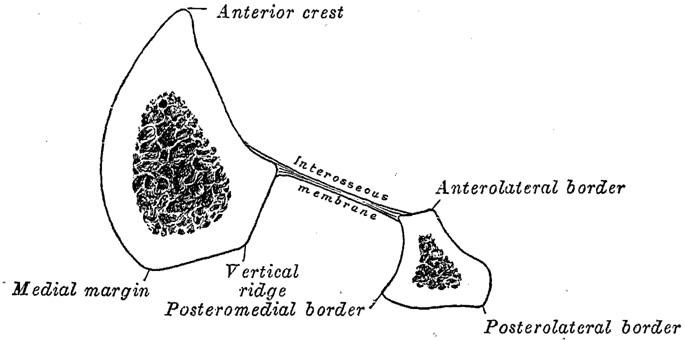
The Fibula

The **fibula** (figs. 430, 431) is placed on the lateral side of the tibia, and is connected to it above and below. In proportion to its length it is the most slender of all the long bones. Its upper end articulates with the back of the lateral condyle of the tibia, below the level of the knee-joint. The bone inclines a little forwards so that its lower end or lateral malleolus is on a plane

anterior to that of the upper end; it projects below the tibia, and forms the lateral part of the ankle-joint.

The **upper end** or **head** of the fibula is of an irregular quadrate form, and has a flattened articular surface, directed upwards, forwards, and medialwards, for articulation with the lateral condyle of the tibia. On its lateral side is a thick and rough prominence, continued behind into a pointed eminence, the *apex* or *styloid process*, which projects upwards from the posterior part of the head. The upper and lateral parts of this prominence give attachment to the tendon of the Biceps femoris and to the fibular collateral ligament of the knee-joint, the ligament dividing the tendon into two parts. The remaining part of the head is rough, for the attachment of muscles and ligaments; in front is a tubercle for the origin of the highest fibres of the Peronæus longus, and a surface for the attachment of the anterior ligament of the head of the bone; behind, is another tubercle for the attachment of the posterior ligament of the head of the fibula, and a few fibres of the Soleus.

FIG. 434.—A transverse section through the right tibia and fibula, showing the attachment of the crural interosseous membrane.



The **body** or **shaft** of the fibula has four borders—anterolateral, anteromedial, posterolateral, and posteromedial; and four surfaces—anterior, posterior, medial, and lateral.

The *anterolateral border* begins above in front of the head, runs vertically downwards to a little below the middle of the bone, and then curving lateralwards, divides to form the sides of a triangular subcutaneous surface which is continued on to the lateral malleolus. This border gives attachment to the anterior fibular intermuscular septum which separates the extensor muscles on the front of the leg from the Peronæus longus and Peronæus brevis on the lateral side

The *anteromedial border*, or *interosseous crest*, is on the medial side of the anterolateral border; it runs close to and nearly parallel with the upper one-third of this border, but diverges from its lower two-thirds. It begins above just below the head of the bone, and is sometimes quite indistinct for about 2·5 cm.; it ends at the apex of a rough triangular surface which is situated above the articular facet of the lateral malleolus. It serves for the attachment of the crural interosseous membrane (fig. 434) which separates the extensor muscles in front from the flexor muscles behind.

The *posterolateral border* is prominent; it begins above at the styloid process of the head and ends below in the posterior border of the lateral malleolus. It is directed lateralwards above, backwards in the middle of its course, backwards and a little medialwards below, and gives attachment to the posterior fibular intermuscular septum which separates the Peronæi on the lateral side from the Soleus and Flexor hallucis longus behind.

The *posteromedial border*, sometimes called the *oblique line*, begins above at the medial side of the head and ends by joining the interosseous crest at the lower part of the bone; it is well marked and prominent in its upper and middle parts. It gives attachment to an aponeurosis which separates the Tibialis posterior from the Soleus and Flexor hallucis longus.

The *anterior surface* is the interval between the anterolateral and anteromedial borders. It is narrow and flat in the upper one-third of its extent; broader and grooved longitudinally in its lower one-third; it serves for the origin of the Extensor digitorum longus, Extensor hallucis longus, and Peronæus tertius.

The *posterior surface* is between the posterolateral and posteromedial borders; it is continuous below with the triangular area above the articular surface of the lateral malleolus, and is directed backwards above, and medialwards below. Its upper one-third is rough for the origin of the Soleus; its lower part, triangular in shape, is connected to the tibia by a strong interosseous ligament; the intervening part gives origin to a portion of the Flexor hallucis longus. Near the middle of this surface is the orifice of the nutrient canal, which is directed downwards.

Fig. 435.—The lower end of the right fibula. Medial aspect.

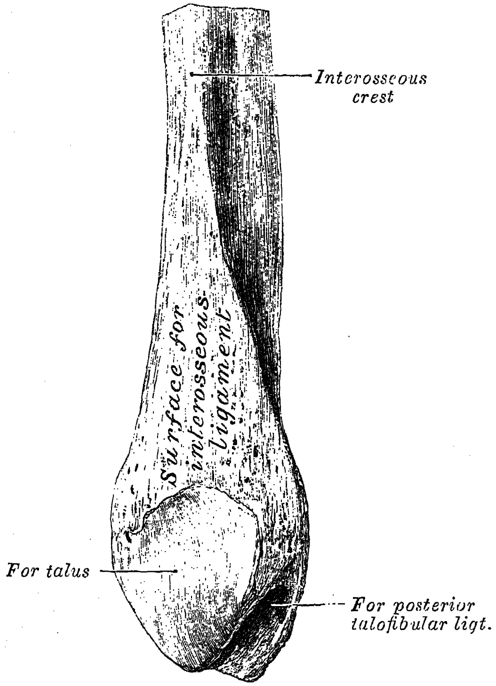
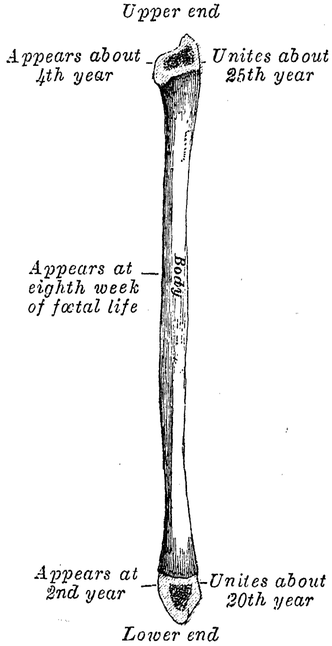


Fig. 436.—A plan of the ossification of the fibula. From three centres.



The *medial surface*, between the anteromedial and posteromedial borders, gives origin to part of the Tibialis posterior.

The *lateral surface*, between the anterolateral and posterolateral borders, is broad and often deeply grooved. It is directed lateralwards in its upper two-thirds, and backwards in its lower one-third, where it is continuous with the posterior border of the lateral malleolus. The upper part of this surface gives origin to the Peronæi longus et brevis; the lower part is covered by the tendons of these muscles.

The **lower end** of the fibula, or *lateral malleolus*, is of a pyramidal form, and somewhat flattened from side to side; it descends to a lower level than the medial malleolus. The *lateral surface* is convex, and continuous with the triangular, subcutaneous surface on the lateral side of the body of the bone. The *medial surface* (fig. 435) presents in front a smooth triangular surface, convex from above downwards, which articulates with the lateral side of the talus. Behind and distal to the articular surface is a rough depression for the attachment of the posterior talofibular ligament. The *anterior border* is thick and rough, and marked below by a depression for the attachment of the anterior talofibular ligament. The *posterior border* is broad, and presents a shallow,

vertical groove which is traversed by the tendons of the Peronæi longus et brevis. The *summit* is rounded, and gives attachment to the calcaneofibular ligament.

Ossification.—The fibula is ossified from three centres (fig. 436): one for the body, and one for either end. Ossification begins in the body about the eighth week of fœtal life, in the lower end during the second year, and in the upper about the fourth year. The lower epiphysis, the first to ossify, unites with the body about the twentieth year; the upper about the twenty-fifth year.

Applied Anatomy.—In fractures of the bones of the leg, both bones are generally involved, but either bone may be broken separately, the fibula more frequently than the tibia. When fracture occurs from indirect force, the break in the tibia is at the junction of the middle with the lower one-third, or weakest part of the bone, while the fracture of the fibula is usually at a rather higher level. These fractures present great variety, both as regards their direction and condition. They may be oblique, transverse, longitudinal, or spiral. When oblique, they are for the most part the result of indirect violence, and the direction of the fracture is downwards, forwards, and medialwards in many cases, but may be downwards and lateralwards, or downwards and backwards. When transverse, the fracture is often at the upper part of the bone, and is the result of direct violence. The spiral fracture of the tibia generally starts as a vertical fissure, involving the ankle-joint, and is associated with fracture of the fibula higher up. It is the result of torsion, from twisting of the body while the foot is fixed.

Fractures of the tibia alone are almost always the result of direct violence, except where the malleolus is broken off by twists of the foot. Fractures of the fibula alone may arise from indirect or direct force, those of the lower end being usually the result of the former, and those higher up being caused by a direct blow on the part; the common peronæal nerve, where it winds round the neck of the fibula, may be injured at the time of the fracture, or subsequently by ill-applied splints.

The tibia is the bone which is most commonly and most extensively distorted in rickets. It bends at the junction of the middle and lower third, its weakest part, and presents a curve forwards with generally some lateral displacement.

The tibia is more often the seat of acute infective necrosis than any other bone in the body, and with the formation of the sequestrum a large amount of new bony material is thrown out by the periosteum. The sequence of events in this disease can be very closely followed in the case of the tibia, and it is not uncommon to find a patient from whom the whole diaphysis of the tibia has been removed, going about with a new bone entirely of periosteal formation. Chronic bone abscess is more frequently met with in the cancellous tissue of the head or lower end of the tibia than in any other bone in the body. These abscesses are very chronic, and in most cases the result of tuberculous ostitis, although they are sometimes due to the organisms of suppuration or even the bacillus typhosus.

The Patella

The **patella** (figs. 437, 438), the largest of the sesamoid bones, is situated in front of the knee-joint in the tendon of the Quadriceps femoris. It is flat and triangular, and has an anterior and a posterior surface, three borders, and an apex.

Fig. 437.—The right patella. Anterior aspect.

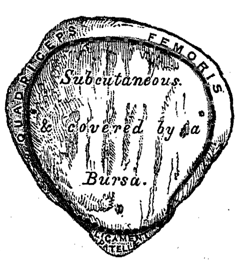


Fig. 438.—The right patella. Posterior aspect.

The *anterior surface* is convex, perforated by apertures for the passage of nutrient vessels, and marked by numerous rough, longitudinal striæ. It is separated from the skin by a bursa and is covered, in the recent state, by an expansion from the tendon of the Quadriceps femoris; this expansion is continuous below with the superficial fibres of the ligamentum patellæ. The *posterior surface* presents above a smooth, oval, articular area, divided into two facets by a vertical ridge; the ridge corresponds to the groove on the patellar surface of the femur, and the facets to the medial and lateral parts of the same surface: the lateral facet is the broader and deeper. Below the articular surface is a rough,

convex, non-articular area, the lower part of which gives attachment to the ligamentum patellæ.

The *base* or *superior border* is thick, and sloped from behind, downwards, and forwards: it gives attachment, except near its posterior margin, to that portion of the Quadriceps femoris which is derived from the Rectus femoris and Vastus intermedius. The *medial and lateral borders* are thinner and converge below: they give attachment to those portions of the Quadriceps femoris which are derived from the Vasti medialis et lateralis. Near the junction of the superior and lateral borders is a small shallow circular depression into which a part of the tendon of the Vastus lateralis is inserted.

The *apex* is pointed, and gives attachment to the ligamentum patellæ.

Structure.—The patella consists of a nearly uniform dense spongy substance, covered by a thin compact lamina. The cancelli immediately beneath the anterior surface are arranged parallel with it. In the rest of the bone they radiate from the articular surface towards the other parts of the bone.

Ossification.—The patella is ossified from a single centre, which usually makes its appearance in the second or third year, but may be delayed until the sixth year. Ossification is completed about the age of puberty.

Applied Anatomy.—Fractures of the patella are of frequent occurrence. They are most often produced by muscular action—that is to say, by violent contraction of the Quadriceps femoris while the limb is in a position of semiflexion, so that the bone is snapped across the condyles of the femur and the fracture is transverse. Fracture of the patella is also produced by direct violence, such as falls on the knee, and here the fracture is usually stellate and the bone comminuted. In fractures by muscular action the medial and lateral retinacular fibres of the articular capsule of the knee-joint are torn, and separation of the fragments takes place. When the fracture is caused by direct violence these retinacular fibres are not torn, and the fragments remain in contact. In fractures by muscular action the fibrous expansion of the Quadriceps femoris which passes over the front of the patella to the ligamentum patellæ is torn from the front of the lower fragment and falls as a veil over the fracture-surface of the upper fragment. Owing to (1) the condition just described, (2) the displacement of the fragments, and (3) the difficulty of maintaining the latter in apposition, union takes place by fibrous tissue which may subsequently stretch, producing wide separation of the fragments and permanent lameness. Really satisfactory results after this fracture are generally only to be obtained by opening the joint, removing the overhanging aponeurosis, and wiring the fragments together.

If the fracture involve only the lower and non-articular part of the bone, it is an anatomical possibility for such to take place without injury to the synovial stratum and without involving the cavity of the knee-joint.

THE SKELETON OF THE FOOT

The skeleton of the foot (figs. 439, 440) consists of three segments: the tarsal bones, the metatarsal bones, and the phalanges or bones of the digits.

The Tarsal Bones (Ossa Tarsi)

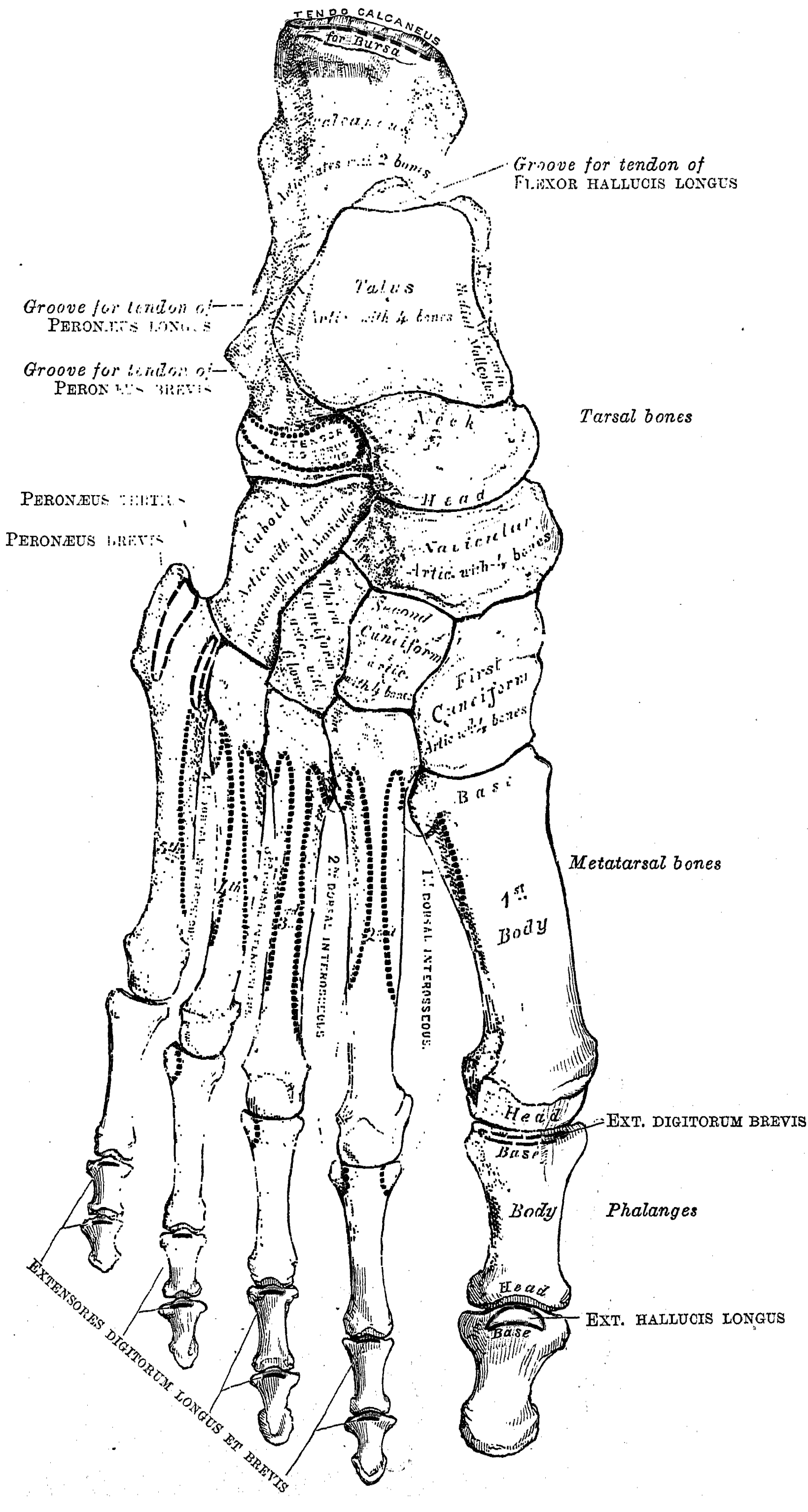
The **tarsal bones** are seven in number: viz. the talus, calcaneus, navicular, first, second, and third cuneiforms, and the cuboid.

The Talus (figs. 441 to 444)

The **talus** (astragalus), the second largest of the tarsal bones, supports the tibia and rests on the calcaneus; it articulates on either side with the corresponding malleolus, and in front with the navicular bone. It consists of a head, neck, body, and trochlea.

The **head** of the talus is directed forwards and medialwards. Its *anterior or navicular surface* is oval and convex, with its long axis running downwards and medialwards; it articulates with the concavity of the navicular bone.

FIG. 439.—The bones of the right foot. Dorsal aspect.



The *internal surface* (fig. 409) of the ala is bounded above by the crest; below by the arcuate line; in front and behind by the anterior and posterior borders. The tendon of the Psoas minor is inserted into the arcuate line. The anterior part of the internal surface, smooth and concave, is termed the *iliac fossa*; it gives origin to the Iliacus, and is perforated posteriorly by a nutrient canal. Behind the iliac fossa is a rough surface, divided into a superior and an inferior portion. The inferior portion or *auricular surface*, so called from its resemblance in shape to the auricula or pinna, articulates with a similar surface on the side of the sacrum. The superior portion, known as the *iliac tuberosity*, is elevated and rough, for the attachment of the short posterior sacro-iliac ligament; it is continuous above and behind with the inner lip of the iliac crest, and here it gives origin to the Sacrospinalis. Below and in front of the auricular surface is the *pre-auricular sulcus*, more commonly present and better marked in the female than in the male; the pelvic portion of the anterior sacro-iliac ligament is attached to this sulcus.

The *crest* of the ilium is convex in its general outline but is sinuously curved, being concave inwards in front, and outwards behind. It is thinner at the middle than at the extremities, and it ends in the anterior and posterior superior iliac spines. The surface of the crest is divided into an external and an internal lip, and an intermediate line; there is a prominent tubercle on the external lip about 5 cm. behind the anterior superior iliac spine. To the external lip are attached, from before backwards, the Tensor fasciæ latæ, Obliquus externus abdominis, and Latissimus dorsi, and along its whole length the fascia lata; to the intermediate line the Obliquus internus abdominis; to the internal lip, the Transversus abdominis, Quadratus lumborum, Sacrospinalis, Iliacus, and the fascia iliaca.

The *anterior border* of the ala presents two projections, separated by a notch. The upper projection, at the junction of the crest and anterior border, is called the *anterior superior iliac spine*; its outer border gives attachment to the fascia lata and the Tensor fasciæ latæ; its inner border, to the Iliacus; its extremity affords attachment to the inguinal ligament, and origin to the Sartorius. Beneath this spine is a notch from which the Sartorius takes origin and across which the lateral femoral cutaneous nerve passes. Below the notch is the *anterior inferior iliac spine* which gives attachment to the straight tendon of the Rectus femoris and to the iliofemoral ligament of the hip-joint. Medial to the anterior inferior iliac spine is a broad, shallow groove, over which the Iliacus descends into the thigh. This groove is bounded medially by the *iliopectineal eminence*, which marks the union of the ilium and the os pubis.

The *posterior border* of the ala, shorter than the anterior, also presents two projections, the *posterior superior* and *posterior inferior iliac spines*, separated by a notch. The former serves for the attachment of the long posterior sacro-iliac ligament; the latter corresponds with the posterior end of the auricular surface. Below the posterior inferior spine is a deep notch, the *greater sciatic notch*.

The **ischium** (os ischii) forms the lowest part of the hip-bone. It is divisible into a body and a superior and an inferior ramus.

The **body** of the ischium enters into and constitutes a little more than two-fifths of the acetabulum. Its *external surface* forms a part of the lunate surface of the acetabulum and a portion of the acetabular fossa. Its *internal surface* is a part of the wall of the lesser pelvis, and gives origin to some fibres of the Obturator internus. Its *posterior surface* is convex, and covered by the Piriformis muscle. Its *antero-inferior border* is thin, and forms a part of the boundary of the obturator foramen; it ends above at the acetabular notch, where it frequently presents a small tubercle, the *posterior obturator tubercle*. Its *lateral border* forms the posterior part of the rim of the acetabulum; from its *medial border* a pointed triangular eminence, the *ischial spine*, extends backwards and medialwards. The external surface of this spine gives attachment to the Gemellus superior; its internal surface to the Coccygeus, Levator ani, and the pelvic fascia; its pointed extremity to the sacrospinous ligament. Above the spine is the *greater sciatic notch*, converted into a foramen by the sacrospinous ligament; this foramen transmits from the pelvis the Piriformis muscle, the superior and inferior glutæal vessels and nerves, the sciatic and posterior femoral cutaneous nerves, the internal pudendal vessels and pudendal

On the *plantar surface* of the head are three articular areas (fig. 442). The largest and hindmost, termed the *middle calcaneal surface*, articulates with the dorsal surface of the sustentaculum tali. Anterior and lateral to this surface, and as a rule continuous with it, is the *anterior calcaneal surface*, quadrilateral

FIG. 441.—The left talus. Dorsal aspect.

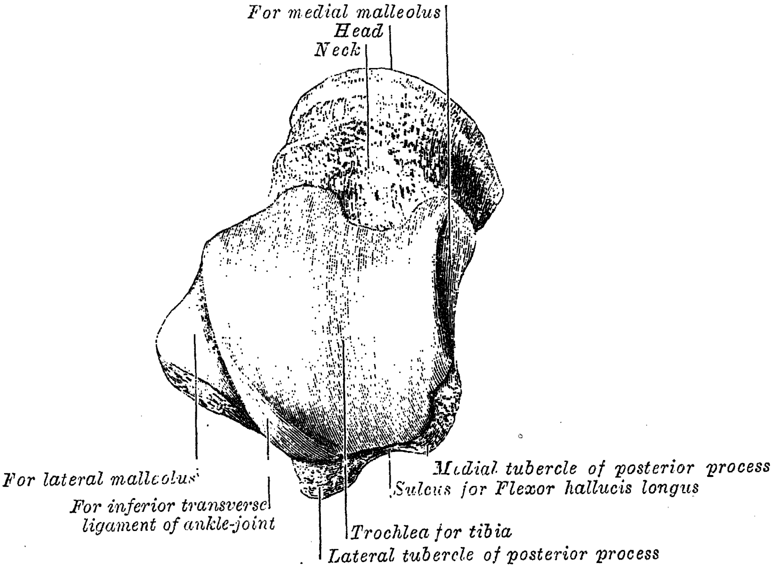
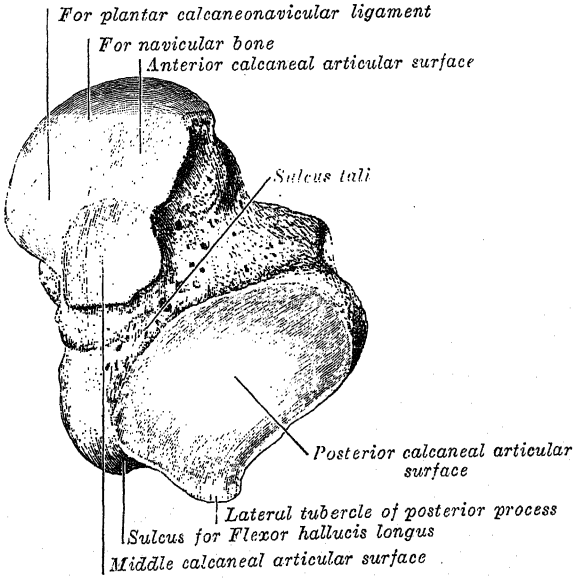


FIG. 442.—The left talus. Plantar aspect.



or irregularly oval in shape, for articulation with the anterior part of the dorsal surface of the calcaneus. Sometimes the anterior and middle calcaneal articular surfaces are wholly or partly discontinuous. Medial to the anterior calcaneal surface is a triangular, convex area, which extends on to the medial side of the head; it rests on the inferior calcaneonavicular ligament and on the anterior part of the deltoid ligament of the ankle-joint.

The **neck** of the talus is the constricted part connecting the head with the body. Its *dorsal and medial surfaces* are rough and perforated by foramina for vessels. The dorsal surface gives attachment to the talonavicular ligament, and a depression on it, immediately in front of the trochlea, receives the anterior edge of the lower end of the tibia when the foot is flexed at the ankle-joint. The *lateral surface* is narrow, concave, and continuous with the *plantar surface*, which consists of the *sulcus tali*, a deep groove, wide in front and narrow behind, and directed forwards and lateralwards ; in the articulated foot the sulcus tali overlies the sulcus calcanei and the two sulci form the *sinus tarsi*, a tunnel which is filled, in the recent condition, with the interosseous talocalcaneal ligament.

FIG. 443.—The left talus. Medial aspect.

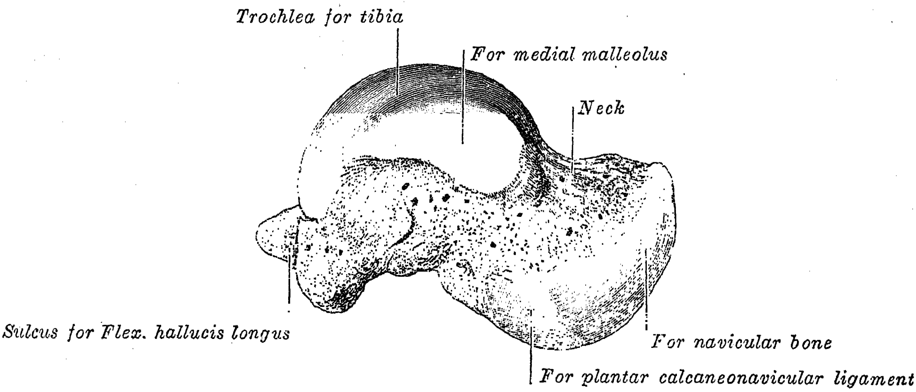
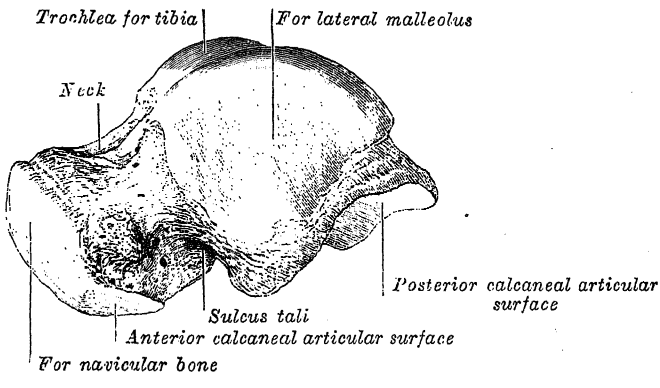


FIG. 444.—The left talus. Lateral aspect.



The **body** of the talus is the cuboidal posterior part of the bone, and from its dorsal surface the articular eminence termed the *trochlea* projects (fig. 441). The dorsal surface of the trochlea articulates with the lower end of the tibia ; it is broader in front than behind, convex from before backwards, and slightly concave from side to side. Its medial margin is straight, but its lateral is curved and inclines medialwards posteriorly where it usually expands into a small triangular facet * which comes into contact with the inferior transverse ligament of the ankle-joint during flexion of that articulation. The medial surface of the trochlea articulates with the medial malleolus : it is pear-shaped, with the blunt end directed forward (fig. 443). Below this surface is a rough, depressed area on the body of the bone for the attachment of the deep part of the deltoid ligament of the ankle-joint. The lateral surface of the trochlea articulates with the lateral malleolus ; it is concave vertically, and triangular in outline with its apex downwards (fig. 444). Below the apex, the body of

* E. Fawcett, *Edinburgh Medical Journal*, 1895.

the talus projects as a rough, triangular eminence, named the *lateral process* ; to it the lateral talocalcaneal ligament is attached. In front of the articular surface for the lateral malleolus is a rough impression for the anterior talofibular ligament, while below and behind it is a groove in which a part of the posterior talofibular ligament is implanted.

On the *plantar surface* of the body (fig. 442) is the *posterior calcaneal surface*, which is large in size and oval in form for articulation with the dorsal surface of the calcaneus. It is limited in front by the sulcus tali and is deeply concave in the direction of its long axis, which runs forwards and lateralwards at an angle of about 45° with the median plane.*

The *posterior surface* of the body is small, and projects backwards as the *posterior process* ; it is traversed in a direction downwards and medialwards by a sulcus for the tendon of the Flexor hallucis longus (fig. 441). On either side of this sulcus is a tubercle. That on the lateral side is the more prominent and gives attachment to the main part of the posterior talofibular ligament ; it is sometimes detached from the rest of the bone, and is then known as the *os trigonum.* To the smaller medial tubercle the medial talocalcaneal ligament is attached.

The Calcaneus (figs. 445 to 448)

The **calcaneus** (os calcis) is the largest of the tarsal bones. It is situated at the lower and posterior part of the foot, and forms a strong lever for the muscles of the calf. It is irregularly cuboidal in shape, having its long axis directed forwards and lateralwards.

Fig. 445.—The left calcaneus. Dorsal aspect.

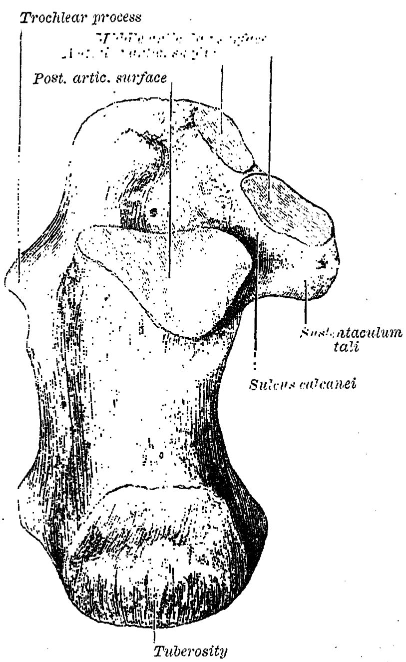
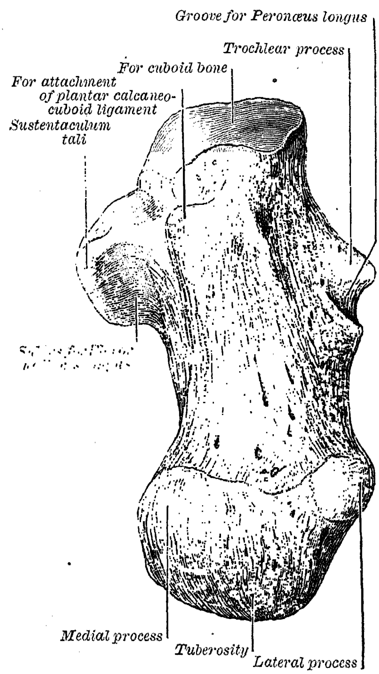


Fig. 446.—The left calcaneus. Plantar aspect.

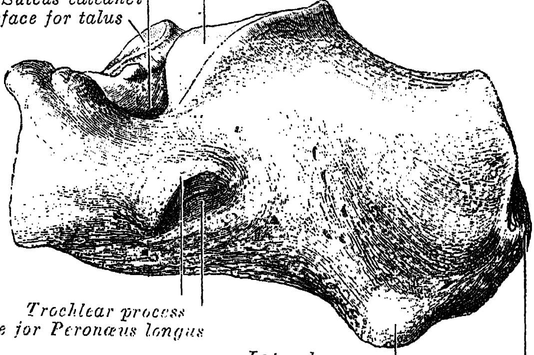


The *dorsal surface* (fig. 445) consists of a posterior non-articular and an anterior articular part. The former varies in length in different individuals, is convex from side to side, concave from before backwards, and supports a

* R. B. S. Sewell (*Journal of Anatomy and Physiology*, vol. xxxviii.) pointed out that in about 10 per cent. of bones a small triangular facet, continuous with the posterior calcaneal facet, is present at the junction of the lateral surface of the body with the posterior wall of the sulcus tali.

mass of fat placed in front of the tendo calcaneus. In front of this area is the *posterior articular surface*, a large, usually somewhat oval-shaped facet, which looks upwards and forwards ; it is convex from behind forwards, and articulates with the posterior calcaneal facet on the plantar surface of the talus. It is bounded anteriorly by a deep depression which is continued backwards and medialwards in the form of a groove, the *sulcus calcanei* ; in the articulated foot this sulcus lies below the sulcus tali, and the two sulci form a tunnel, the sinus tarsi, already referred to (p. 338). In front and medial to this sulcus is an elongated facet, concave from behind forwards, and with its long diameter directed forwards and lateralwards. This facet is frequently divided into two parts : of these, the posterior and larger is termed the *middle articular surface* ; it is supported on a projecting process of bone, the *sustentaculum tali*, and articulates with the middle calcaneal facet on the plantar surface of the talus ; the anterior and lesser, termed the *anterior articular surface*, is placed on the front part of the body, and articulates with the anterior calcaneal facet on the plantar surface of the talus. The dorsal surface, anterior and lateral to the facets, is rough for the attachment of ligaments and for the origin of the Extensor digitorum brevis.

Fig. 447.—The left calcaneus. Lateral aspect.



The *plantar surface* (fig. 446) is uneven, wider behind than in front, and convex from side to side ; it is bounded posteriorly by the lower part of the calcaneal tuberosity, which presents a medial and a lateral process ; the *lateral process*, small, prominent, and rounded, gives origin to part of the Abductor digiti quinti ; the *medial process*, broader and larger, gives attachment, by its prominent medial margin, to the Abductor hallucis, and in front to the plantar aponeurosis and the Flexor digitorum brevis ; from the depression between the processes a part of the Abductor digiti quinti takes origin. The rough surface in front of the processes gives attachment to the long plantar ligament and the lateral head of the Quadratus plantæ ; to a prominent tubercle near the anterior part of this surface and to a transverse groove in front of the tubercle, the plantar calcaneocuboid ligament is attached.

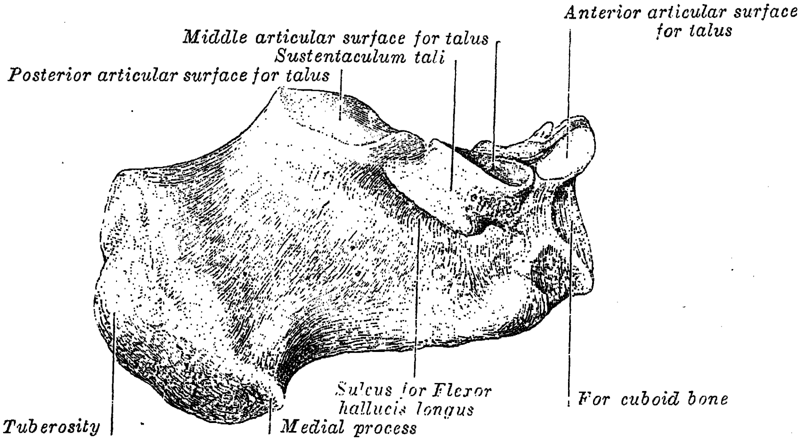
The *lateral surface* (fig. 447) is broad behind, and narrow in front, flat and almost subcutaneous ; near its centre is a small tubercle, for the attachment of the calcaneofibular ligament. Below and in front of this tubercle is a ridge, the *trochlear process* (peronæal tubercle), which is often indistinctly marked. It gives attachment to the inferior peronæal retinaculum, and separates two grooves ; the superior groove transmits the tendon of the Peronæus brevis ; the inferior, that of the Peronæus longus.

The *medial surface* (fig. 448) is directed obliquely downwards and forwards, and is deeply concave ; above the anterior part of the concavity is a shelf-like projection, the *sustentaculum tali*. The dorsal surface of the sustentaculum tali is concave, and articulates with the middle calcaneal articular surface of the talus ; its plantar surface is grooved for the tendon of the Flexor hallucis

longus; the narrow, medial surface is overlaid by the tendon of the Flexor digitorum longus, and is grooved near its upper margin for the attachment of a part of the deltoid ligament of the ankle-joint. The anterior margin of the sustentaculum tali gives attachment to the plantar calcaneonavicular ligament.

The *anterior extremity* or articular surface for the cuboid bone is of a somewhat triangular form. It is concave from above downwards and lateralwards, and convex in a direction at right angles to this. Its medial border gives attachment to the plantar calcaneonavicular ligament.

Fig. 448.—The left calcaneus. Medial aspect.



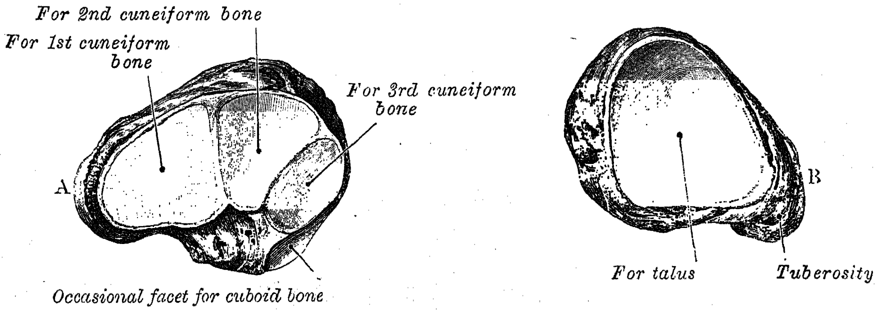
The *posterior extremity* or *calcaneal tuberosity* is prominent, convex, wider below than above, and divisible into three areas. The lowest of these areas is rough, and covered by the fatty and fibrous tissue of the heel; the middle, also rough, gives insertion to the tendo calcaneus and Plantaris; while the highest is smooth, and is covered by a bursa which intervenes between this part of the tuberosity and the tendo calcaneus. The plantar surface of this tuberosity displays the medial and lateral processes already described (p. 340).

The Navicular Bone (Os Naviculare Pedis)

The **navicular bone** (fig. 449) is situated at the medial side of the tarsus, between the talus behind and the cuneiform bones in front.

The *anterior surface* is convex from side to side, and subdivided by two ridges into three facets, for articulation with the three cuneiform bones. The

Fig. 449.—The left navicular bone. A. Anterior aspect. B. Posterior aspect.



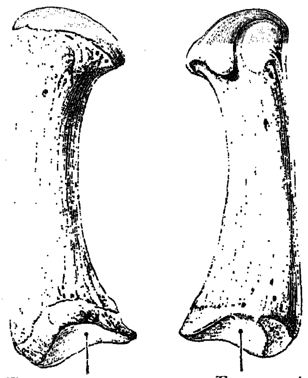
posterior surface, oval and concave, articulates with the anterior surface of the head of the talus. The *dorsal surface* is convex from side to side, and rough

is broader, and extends farther proximalwards on the volar than on the dorsal surface, and its transverse diameter is the shorter. On either side of the head is a deep depression, and behind this a tubercle for the attachment of one of the collateral ligaments of the metacarpophalangeal joint. The *dorsal surface*, broad and flat, supports the extensor tendons; the *volar surface* is grooved for the flexor tendons, and marked on either side by an articular eminence continuous with the terminal articular surface.

The Characteristics of the Individual Metacarpal Bones

The **first metacarpal bone** (fig. 402), shorter and stouter than the others, diverges from the second, and its volar surface is directed medialwards. The *body* is flattened and broad on its dorsal surface, and does not present the ridge which is found on the other metacarpal bones; its volar surface is concave from above downwards. The Opponens pollicis is inserted into its radial border; the lateral head of the first Interosseus dorsalis arises from its ulnar border. The *base* presents a concavoconvex surface, for articulation with the greater multangular bone; it has no facets on its sides, but on its lateral side is a tubercle for the insertion of the Abductor pollicis longus. The *head* is less convex than the heads of the other metacarpal bones, and is broader from side to side than from before backwards. On its volar surface are two articular eminences, of which the lateral is the larger; on these surfaces sesamoid bones glide.

Fig. 402.—The first left metacarpal bone.



The **second metacarpal bone** (fig. 403) is the longest, and its base the largest, of the four remaining bones. Its *base* is deeply grooved, and medial to the groove is a prominent ridge. The base presents four articular facets: three on the proximal, and one on the medial surface. Of the facets

Fig. 403.—The second left metacarpal bone.

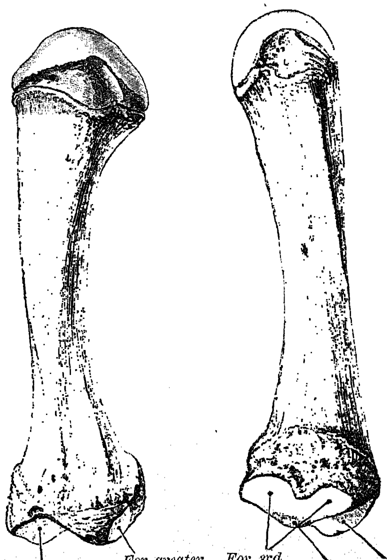
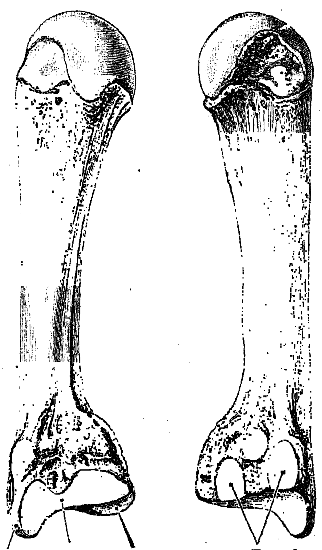


Fig. 404.—The third left metacarpal bone.



The *anterior surface*, triangular in form, articulates with the base of the second metatarsal bone. The *posterior surface*, also triangular, articulates with the intermediate facet on the anterior surface of the navicular bone. On the *medial surface* is an L-shaped facet, running along the superior and posterior borders, for articulation with the first cuneiform bone; the rest of the surface is rough for the attachment of ligaments. The *lateral surface* presents posteriorly a vertical facet for articulation with the third cuneiform bone. The *dorsal surface* or base of the wedge is quadrilateral and rough

Fig. 451.—The second left cuneiform bone.

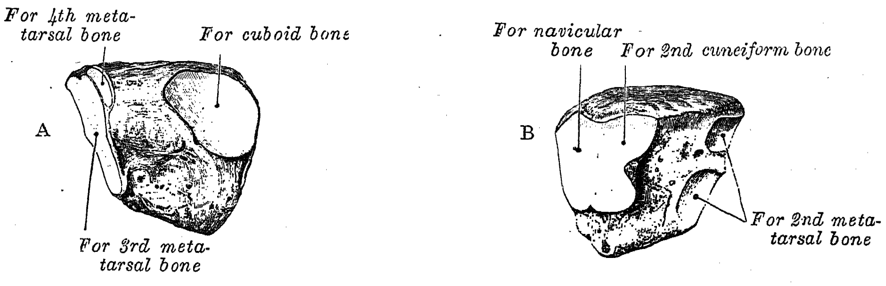
A. Anteromedial aspect. B. Posterolateral aspect.

for the attachment of ligaments. The *plantar surface*, sharp and tuberculated, is also rough for the attachment of ligaments, and for the insertion of a slip from the tendon of the Tibialis posterior.

The **third cuneiform bone** (os cuneiforme tertium) (fig. 452) has its base directed upwards; it is placed between the second cuneiform and cuboid bones.

The *anterior surface*, triangular in form, articulates with the base of the third metatarsal bone. The *posterior surface* articulates with the lateral facet on the anterior surface of the navicular bone, and is rough below for the attachment of ligamentous fibres. The *medial surface* presents an anterior and a posterior articular facet: the anterior, sometimes divided into two, articulates with the lateral side of the base of the second metatarsal bone; the posterior skirts the posterior border, and articulates with the second cuneiform bone; the intervening rough area gives attachment to an interosseous ligament. The *lateral surface* also presents two articular facets; the anterior one, situated at the

Fig. 452.—The third left cuneiform bone. A. Anterolateral aspect. B. Posteromedial aspect.

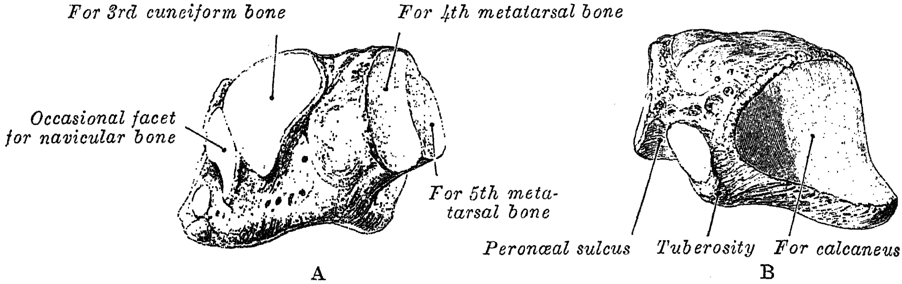


superior angle of the bone, is small and semi-oval in shape, and articulates with the medial side of the base of the fourth metatarsal bone; the posterior and larger one is triangular or oval, and articulates with the cuboid bone; the intervening, rough, non-articular area serves for the attachment of an interosseous ligament. The *dorsal surface* or base of the wedge is of an oblong form, its posterolateral angle being prolonged backwards. The *plantar surface* is narrow and rounded, and serves for the attachment of ligaments and parts of the tendons of the Tibialis posterior and Flexor hallucis brevis.

The Cuboid Bone (Os Cuboideum)

The **cuboid bone** (fig. 453) is placed on the lateral side of the foot, in front of the calcaneus, and behind the fourth and fifth metatarsal bones.

Fig. 453.—The left cuboid bone. A. Anteromedial aspect. B. Posterolateral aspect.



The *dorsal surface*, directed upwards and lateralwards, is rough for the attachment of ligaments. The *plantar surface* is crossed in front by a deep groove, the *peronæal sulcus*, which runs obliquely forwards and medialwards; it lodges the tendon of the Peronæus longus, and is bounded behind by a prominent ridge, to which the long plantar ligament is attached. The ridge ends laterally in the *tuberosity*, the lateral part of which carries an oval facet; on this facet the sesamoid bone or cartilage which is frequently found in the tendon of the Peronæus longus glides. Behind the peronæal sulcus the bone is rough, for the attachment of the plantar calcaneocuboid ligament, a few fibres of the Flexor hallucis brevis, and a fasciculus from the tendon of the Tibialis posterior. On the *lateral surface* is a deep notch which marks the commencement of the peronæal sulcus. The *posterior surface* is smooth, triangular, and concavoconvex, for articulation with the anterior surface of the calcaneus; its plantar, medial angle projects backwards as a process which underlies and supports the anterior end of the calcaneus. The *anterior surface* is divided by a vertical ridge into two facets; the medial, quadrilateral in form, articulates with the fourth metatarsal bone; the lateral, triangular, with the fifth. The *medial surface* is irregularly quadrilateral, and at its middle and dorsal part is a smooth oval facet, for articulation with the third cuneiform bone; behind this a small facet for articulation with the navicular bone is frequently present; the rest of this surface is rough for the attachment of interosseous ligaments.

The Metatarsal Bones (Ossa Metatarsi)

The **metatarsal bones**, five in number, are enumerated from the medial side of the foot.

The Common Characteristics of the Metatarsal Bones

Each metatarsal bone has a body, a base or proximal end, and a head or distal end.

The **body** of each bone is prismoid in form; it tapers gradually from the base to the head, and is slightly convex longitudinally on its dorsal surface.

The **base** articulates with the tarsus, and with the contiguous metatarsal bones.

The **head** articulates with the proximal phalanx by a convex articular surface which extends farther backwards on the plantar than on the dorsal surface; the plantar extension ends on either side on the summit of a slight

articular eminence. The sides of the head are flattened and on each is a depression surmounted by a tubercle for the attachment of one of the collateral ligaments of the metatarsophalangeal joint.

The Characteristics of the Individual Metatarsal Bones

The **first metatarsal bone** (fig. 454) is the shortest and thickest of the metatarsal bones. The *body* is strong, and of well-marked prismoid form. The *base* has, as a rule, no articular facets on its sides, but there is occasionally one on the lateral side for articulation with the second metatarsal bone. Its proximal articular surface, of large size and kidney-shaped, articulates with the first cuneiform bone; its circumference is grooved, for the tarsometatarsal ligaments, and medially gives insertion to a part of the tendon of the Tibialis anterior; its plantar angle presents a rough, oval prominence for the insertion of the tendon of the Peronæus longus. The *head* is large; on its plantar surface is a median elevation separating two grooved facets on which sesamoid bones glide.

Fig. 454.—The first left metatarsal bone.

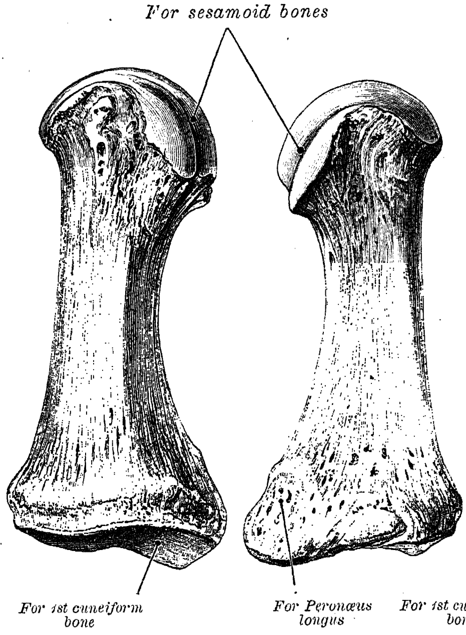
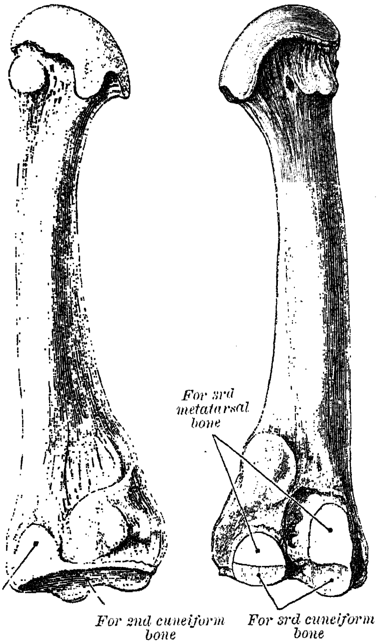


Fig. 455.—The second left metatarsal bone.



The **second metatarsal bone** (fig. 455) is the longest of the metatarsal bones. On its wedge-shaped *base* are four articular facets: one on its proximal surface, of a triangular form, for articulation with the second cuneiform bone; one at the upper part of its medial surface, for articulation with the first cuneiform bone; and two on its lateral surface, an upper and lower, separated by a rough non-articular interval. Each of these lateral articular surfaces is divided by a vertical ridge; the two anterior facets articulate with the third metatarsal bone; the two posterior (sometimes continuous) with the third cuneiform bone. A fifth facet is occasionally present for articulation with the first metatarsal bone; it is oval in shape, and is situated on the medial side of the base, distal to the facet for the first cuneiform bone.

The **third metatarsal bone** (fig. 456) has a triangular *base* which articulates proximally with the third cuneiform bone; medially it articulates by two facets with the second metatarsal bone; and laterally, by a single facet situated at the dorsal angle, with the fourth metatarsal bone.

The **fourth metatarsal bone** (fig. 457) is smaller than the third. On the proximal surface of its *base* is an oblique quadrilateral facet for articulation with the cuboid bone; on its lateral side a single facet, for the fifth metatarsal bone; on its medial side a facet divided by a ridge into an anterior portion for the third metatarsal bone, and a posterior portion for the third cuneiform bone.

Fig. 456.—The third left metatarsal bone.

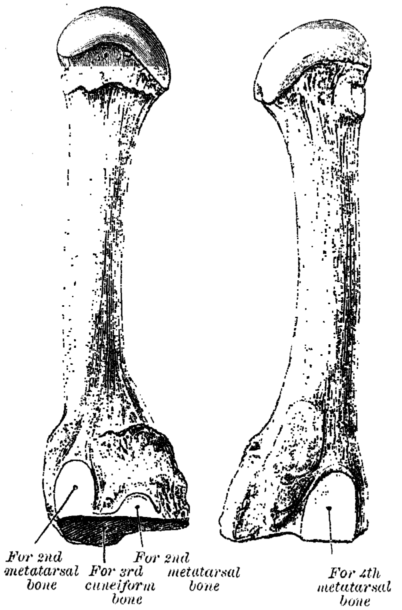


Fig. 457.—The fourth left metatarsal bone.

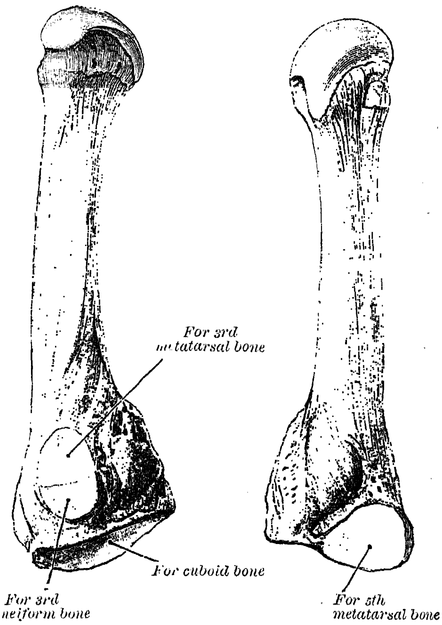
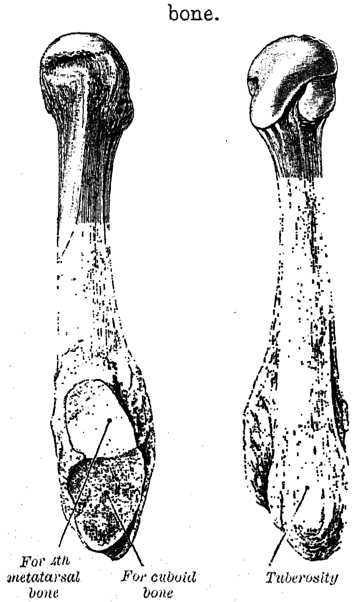


Fig. 458.—The fifth left metatarsal bone.



The **fifth metatarsal bone** (fig. 458) is recognised by a rough eminence, the *tuberosity*, on the lateral side of its base. The *base* articulates proximally, by a triangular, obliquely cut surface, with the cuboid bone; and medially, with the fourth metatarsal bone. On the medial part of its dorsal surface is inserted the tendon of the Peronæus tertius, and on the dorsal surface of the tuberosity that of the Peronæus brevis. A strong band of the plantar aponeurosis connects the projecting part of the tuberosity with the lateral process of the tuberosity of the calcaneus. The plantar surface of the base is grooved for the tendon of the Abductor digiti quinti, and gives origin to the Flexor digiti quinti brevis.

The Phalanges of the Foot (Phalanges Digitorum Pedis)

The **phalanges** of the foot correspond in number and general arrangement with those of the hand; there are two in the great toe, and three in each of the other toes. They are, however, much smaller, and their bodies, especially those of the bones of the first row, are compressed from side to side.

The phalanges of the **first row** closely resemble those of the hand. The *body* of each is compressed from side to side, convex above, concave below. The *base* is concave for articulation with the head of the corresponding metatarsal bone, and on the *head* is a trochlear surface for articulation with the second phalanx.

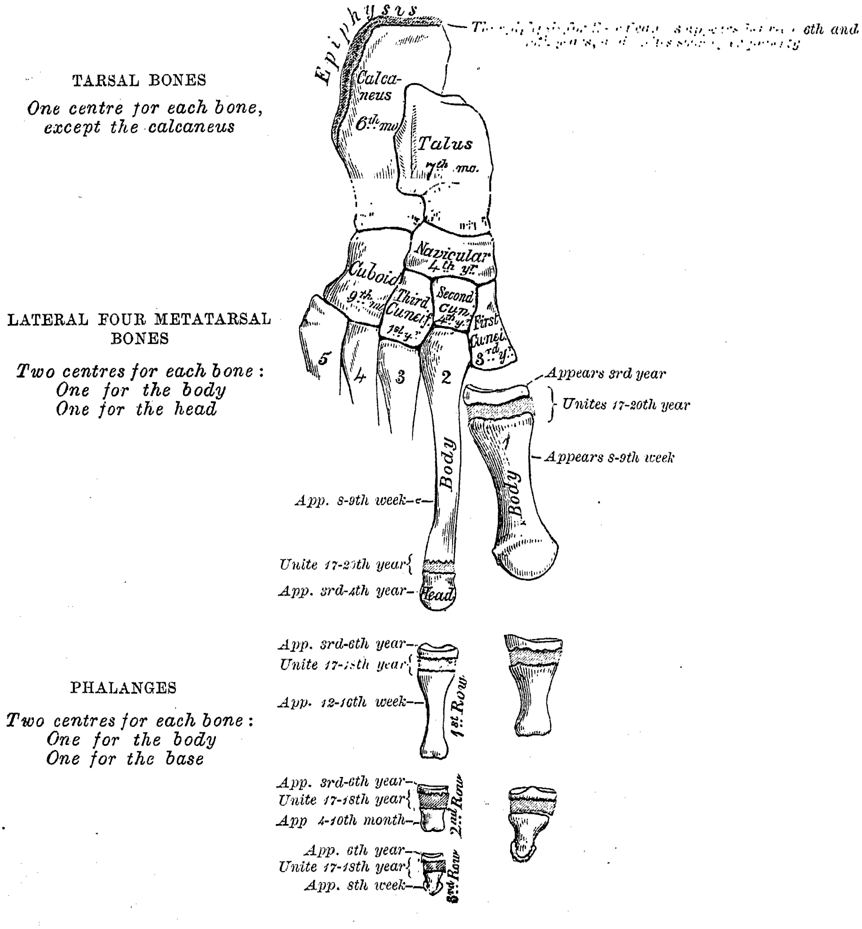
The phalanges of the **second row** are remarkably small and short, but rather broader than those of the first row.

The **ungual phalanges** resemble those of the fingers; but they are smaller, and are flattened from above downwards; each presents a broad base for articulation with the corresponding bone of the second row, and an expanded distal extremity for the support of the nail and the end of the toe.

Ossification of the Bones of the Foot (fig. 459)

The **tarsal bones** are each ossified from a single centre, excepting the calcaneus which has an epiphysis for its tuberosity. The centres make their appearance as

Fig. 459.—A plan of the ossification of the bones of the foot.



follows: in the calcaneus, at the sixth month of fœtal life; in the talus, about the seventh month; in the cuboid, at the ninth month; in the third cuneiform, during the first year; in the first cuneiform, during the third year; in the second cuneiform and navicular, during the fourth year. The epiphysis for the tuberosity of the calcaneus begins to ossify between the sixth and tenth years, and unites with the rest of the bone soon after puberty. The lateral tubercle of the posterior process

of the talus is sometimes ossified from an independent centre, and may remain separate from the rest of the bone, when it is named the *os trigonum*.

The **metatarsal bones** are each ossified from two centres: a primary centre for the body, and a secondary or epiphysial centre for the base or proximal end of the first, and for the head or distal end of each of the other four.* Ossification begins in the middle of the body about the eighth or ninth week of fœtal life. The epiphysis for the base of the first metatarsal appears about the third year; those for the heads of the other metatarsals between the third and fourth years; all unite with the bodies between the seventeenth and twentieth years. An epiphysis is frequently present on the tuberosity of the base of the fifth metatarsal bone (Holland).†

The **phalanges** are each ossified from two centres: a primary one for the body and an epiphysis for the base. The primary centres for the ungual phalanges appear about the eighth week of fœtal life; those for the first phalanges between the twelfth and sixteenth weeks, and those for the second phalanges after the sixteenth week (that for the second phalanx of the fifth toe does not usually appear until after birth). The epiphysial centres appear between the third and sixth years, and unite with the bodies about the seventeenth or eighteenth year.

Comparison of the Bones of the Hand and Foot

The hand and foot are constructed on somewhat similar principles, each consisting of a proximal part, the carpus or tarsus, an intermediate portion, the meta-

Fig. 460.—The skeleton of the left foot. Medial aspect.

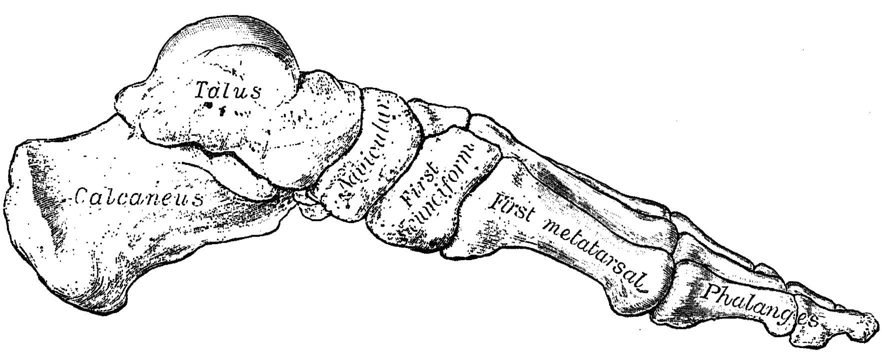
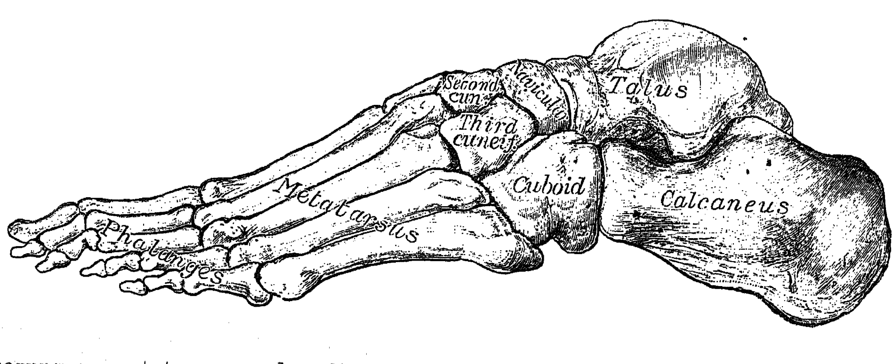


Fig. 461.—The skeleton of the left foot. Lateral aspect.



carpus or metatarsus, and a distal portion, the phalanges. The proximal part consists of a series of more or less cubical bones which allow a slight amount of gliding on one another and are chiefly concerned in distributing forces transmitted to or from the bones of the arm or leg. The intermediate part is made up of slightly

* As in the first metacarpal bone (see footnote, page 306), so in the first metatarsal, there is often a second epiphysis for the head.

† C. Thurstan Holland, *Journal of Anatomy*, vol. lv., 1921.

movable long bones which assist the carpus or tarsus in distributing forces and also give greater breadth for the reception of such forces. The separation of the individual bones from one another allows of the attachments of the interosseous muscles and protects the dorsipalmar and dorsiplantar vascular anastomoses. The distal portion is the most movable, and its separate elements enjoy a varied range of movements, the chief of which are flexion and extension.

The functions of the hand and foot are, however, very different, and the general similarity between them is greatly modified to meet these requirements. Thus the foot forms a firm basis of support for the body in the erect posture, and is therefore more solidly built, and its component parts are less movable on each other than those of the hand. In the case of the phalanges the difference is readily noticeable; those of the foot are smaller and their movements more limited than those of the hand. Very much more marked is the difference between the metacarpal bone of the thumb and the metatarsal bone of the great toe. The metacarpal bone of the thumb is constructed to permit of great mobility; it is directed at an acute angle from that of the index finger, and is capable of a considerable range of movement at its articulation with the carpus. The metatarsal bone of the great toe assists in supporting the weight of the body, is constructed with great solidity, lies parallel with the other metatarsals, and has a very limited degree of mobility. The carpus is small in proportion to the rest of the hand, is placed in line with the forearm, and forms a transverse arch, the concavity of which constitutes a bed for the flexor tendons. The tarsus forms a considerable part of the foot, and is placed at right angles to the leg, a position which is almost peculiar to man, and has relation to his erect posture. In order to allow of their supporting the weight of the body with the least expenditure of material the tarsus and metatarsus are constructed in a series of arches (figs. 460, 461), the disposition of which will be considered after the articulations of the foot have been described.

Applied Anatomy.—Considering the injuries to which the foot is subjected, it is surprising how seldom the tarsal bones are fractured. This is no doubt due to the fact that the tarsus is composed of a number of bones, articulated by a considerable extent of surface, and joined together by very strong ligaments which serve to break the force of violence applied to this part of the body. When fracture does occur, these bones being composed for the most part of a soft cancellous structure, covered only by a thin shell of compact tissue, are often extensively comminuted, especially as most of the fractures are produced by direct violence; and, as there is only a very scanty amount of soft parts over the bones, the fractures are very often compound, and amputation is often necessary.

When fracture occurs in the anterior group of tarsal bones, it is almost invariably the result of direct violence; but fractures of the posterior group—that is, of the calcaneus and talus—are usually produced by falls from a height on to the feet.

In club-foot (talipes), especially in congenital cases, the bones of the tarsus become altered in shape and size, and displaced from their proper positions. This is principally the case in congenital talipes equinovarus, in which the head of the talus becomes twisted and atrophied, and a similar condition may be present in the other bones, more especially the navicular.

The tarsal bones are peculiarly liable to become the seat of tuberculous caries following comparatively trivial injuries. Caries of the calcaneus or talus may remain limited to the one bone for a long period, but when one of the other bones is affected, the remainder frequently become involved, since the disease spreads through the large and complicated synovial stratum which is more or less common to these bones.

Amputation of the foot is often required either for injury or disease. The principal amputations are as follows: (1) Syme's: amputation at the ankle-joint by a heel-flap, with removal of the malleoli and sometimes a thin slice from the lower end of the tibia. (2) Pirogoff's: amputation of the whole of the tarsal bones (except the posterior part of the calcaneus), and a thin slice from the tibia and fibula including the two malleoli. The sawn surface of the calcaneus is then turned up and united to the cut surface of the tibia. (3) Subastragalar: amputation of the foot below the talus through the joint between it and the calcaneus.

The bones of the tarsus occasionally require removal individually. This is especially the case with the talus for tuberculous disease limited to that bone; or the talus may require excision in cases of subastragalar dislocation, or in cases of inveterate talipes. The cuboid has been removed for the same reason.

The metatarsal bones, and especially that of the great toe, are frequently diseased, either in tuberculous subjects or in patients with perforating ulcer of the foot.

THE SESAMOID BONES *

The **sesamoid bones** are small more or less rounded masses of bone embedded in certain tendons and usually related to joint-surfaces. Their functions probably are to modify pressure, to diminish friction, and occasionally to alter the direction of the pull of a muscle. That they are not developed to meet certain physical requirements in the adult is evidenced by the fact that they are present as cartilaginous nodules in the fœtus, and in greater numbers than in the adult. They must be regarded as integral parts of the skeleton phylogenetically inherited.† Physical necessities probably come into play in selecting and in regulating the degree of development of the original cartilaginous nodules.

Sesamoid bones are invested by the fibrous tissue of the tendons, except on the surfaces in contact with the parts over which they glide, where they present smooth articular facets.

In the upper extremity the sesamoid bones of the joints are found only on the palmar surface of the hand. Two, of which the medial is the larger, are present at the metacarpophalangeal joint of the thumb ; one is frequently present in the corresponding joint of the index finger, and one (or two) in the same joint of the little finger. Sesamoid bones are found occasionally at the metacarpophalangeal joints of the middle and ring fingers, at the interphalangeal joint of the thumb, and at the distal interphalangeal joint of the index finger.

In the lower extremity the largest sesamoid bone of the joints is the patella, developed in the tendon of the Quadriceps femoris. On the plantar aspect of the foot, two, of which the medial is the larger, are always present at the metatarsophalangeal joint of the great toe ; one sometimes at the metatarsophalangeal joints of the second and fifth toes, one occasionally at the corresponding joints of the third and fourth toes, and one at the interphalangeal joint of the great toe.

Sesamoid bones apart from joints are seldom found in the tendons of the upper limb ; one is sometimes seen in the tendon of the Biceps brachii opposite the radial tuberosity. They are, however, present in several of the tendons of the lower limb—viz. one in the tendon of the Peronæus longus, where it glides on the cuboid bone ; one, appearing late in life, in the tendon of the Tibialis anterior, opposite the smooth facet of the first cuneiform bone ; one in the tendon of the Tibialis posterior, opposite the medial side of the head of the talus ; one in the lateral head of the Gastrocnemius, behind the lateral condyle of the femur ; and one in the tendon of the Psoas major, where it glides over the os pubis. Sesamoid bones are found occasionally in the tendons which wind round the medial and lateral malleoli, and one is sometimes present in the tendon of the Glutæus maximus where it passes over the greater trochanter of the femur.

* Consult an article by A. H. Bizarro, *Journal of Anatomy*, vol. lv., 1921.

† Thilenius, *Morpholog. Arbeiten*, v., 1896.

SYNDESMOLOGY

THE bones of the skeleton are connected to one another at different parts of their surfaces, and such connexions are termed *joints* or *articulations*. Where the joints are *immovable*, as in the articulations of the cranium, the opposed margins of the bones are nearly in contact, being separated merely by a thin layer of fibrous membrane, named the *sutural ligament*; in certain regions at the base of the skull this fibrous membrane is replaced by a layer of cartilage. Where *slight movement* combined with great strength is required, the opposed osseous surfaces are united by tough and elastic *fibrocartilages*, as in the joints between the vertebral bodies, and in the interpubic articulation. In the *freely movable* joints the opposed surfaces are completely separated from one another; the parts of the bones forming the articulations are expanded for greater convenience of mutual connexion, and are covered with *hyaline articular cartilage*, while the joints are enveloped by *articular capsules*, and are usually strengthened by strong fibrous bands called *ligaments*.

In long bones the ends are the parts which form the articulations; they are somewhat enlarged, and consist of spongy substance with a thin coating of compact substance. In the flat bones the articulations usually take place at the edges, and in the short bones at various parts of their surfaces. The layer of compact bone which forms the joint surface, and to which the articular cartilage is attached, is called the *articular lamella*; its lacunæ are large, but it contains no Haversian canals or canaliculi. The vessels of the spongy substance approach the articular lamella but do not perforate it; this lamella is consequently denser and firmer than ordinary bone.

The **articular cartilage** which covers the articular surfaces of bones, and the **fibrocartilage** which enters into the structure of some of the joints, are described in the section on Histology (pp. 14 to 17).

The **ligaments** are composed mainly of parallel or closely interlaced bundles of *white fibrous tissue*, and present a silvery appearance. They are pliant and flexible, so as to allow perfect freedom of movement, but strong, tough, and inextensible, so as not to yield readily to applied force. Some ligaments consist entirely of *yellow elastic tissue*, as the ligamenta flava which connect together the laminæ of adjacent vertebræ, and the ligamentum nuchæ in the lower animals. In these cases the elasticity of the ligament is intended to act as a substitute for muscular power.

The **articular capsules** form complete envelopes for the freely movable joints. Each capsule consists of two strata—an external (stratum fibrosum) composed of white fibrous tissue, and an internal (stratum synoviale) which is sometimes described separately as the synovial membrane of the joint.

The *stratum fibrosum* is attached to the circumferences of the articular ends of the bones entering into the joint, and thus entirely surrounds the articulation.

The *stratum synoviale* invests the inner surface of the stratum fibrosum, is reflected over any tendons passing through the joint-cavity, and ceases at the margins of the articular cartilages. It is composed of a thin, delicate,

connective tissue, and is covered on its free surface with a layer of endothelium. In some joints it is thrown into folds which pass across the cavity, as in the knee-joint; in others there are flattened folds, subdivided at their margins into fringe-like processes which contain convoluted vessels. These folds generally project near the margin of the cartilage, and lie flat upon its surface. The endothelium of the stratum synoviale secretes a small quantity of viscid, lubricating fluid, termed *synovia*.

Closely related in structure and function to the synovial stratum of the articular capsule, and therefore conveniently described in this section, are the vaginæ mucosæ of tendons and the bursæ mucosæ.

Vaginæ mucosæ (mucous sheaths) serve to facilitate the gliding of tendons in fibro-osseous canals, e.g. the tendons of the flexor and extensor muscles of the fingers and toes as they pass through canals in or near the hand and foot. Each sheath has the form of an elongated closed sac which lines the wall of the canal, and is reflected upon the surface of the enclosed tendon or tendons.

Bursæ mucosæ are interposed between surfaces which glide upon each other. They consist of closed sacs containing a minute quantity of clear viscid fluid, and may be grouped, according to their situations, under the headings *subcutaneous*, *submuscular*, *subfascial*, and *subtendinous*.

A CLASSIFICATION OF THE JOINTS

Joints are divided into three classes: *synarthroses* or immovable, *amphiarthroses* or slightly movable, and *diarthroses* or freely movable joints.

1. Synarthroses. (Immovable Articulations)

Synarthroses are articulations in which the surfaces of the bones are fastened together by intervening connective tissue or hyaline cartilage, and in which there is no appreciable motion, as in the joints between the bones of the cranium. There are three varieties of synarthrosis: sutura, gomphosis, and synchondrosis.

Sutura is an articulation met with only in the skull, where the margins of the bones articulate with one another (fig. 462). The margins of the bones are not in direct contact, being separated by a thin layer of fibrous tissue, continuous externally with the pericranium, internally with the dura mater.

Fig. 462.—A section through the sagittal suture.

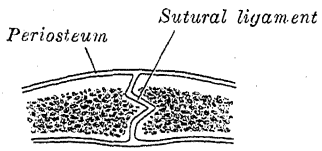
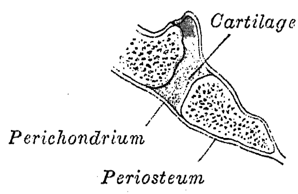


Fig. 463.—A section through the occipito-sphenoidal synchondrosis of an infant.



When the bony margins are connected by a series of interlocking, tooth-like processes, the articulation is named *sutura serrata*, as in the sagittal suture. When the articulation is formed by one bone overlapping another, as in the suture between the temporal and parietal bones, it is termed *sutura squamosa*; where there is simple apposition of contiguous rough surfaces, as between the palatine processes of the maxillæ, or between the horizontal parts of the palatine bones, it is named *sutura harmonia*.

Gomphosis is articulation by the insertion of a conical process into a socket; it is seen in the articulations of the roots of the teeth with the alveoli of the mandible and maxillæ.

Synchondrosis.—Where the connecting medium is cartilage the joint is termed a synchondrosis (fig. 463); this is a temporary form of joint, for the cartilage is ultimately converted into bone. Such joints are found between the epiphyses and bodies of long bones, between the occipital and sphenoidal bones at and for some years after birth, and between the petrous portions of the temporal bones and the jugular process of the occipital bone.

2. Amphiarthroses. (Slightly Movable Articulations)

In these articulations the contiguous bony surfaces are either united by an interosseous ligament, as in the inferior tibiofibular articulation, or are covered with articular cartilage and connected by broad flattened discs of fibrocartilage, of a more or less complex structure, as in the articulations between the bodies of the vertebræ. The first form is termed a **syndesmosis**, the second a **symphysis** (fig. 464).

3. Diarthroses. (Freely Movable Articulations)

This class includes the majority of the joints. In a diarthrodial joint the contiguous bony surfaces are covered with articular cartilage, and connected by an articular capsule and ligaments (fig. 465).

Fig. 464.—A section through a symphysis. Diagrammatic.

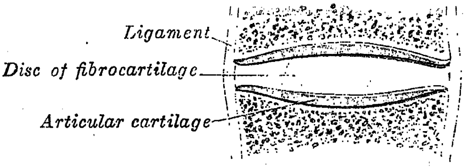


Fig. 465.—A section through a simple diarthrodial joint. Diagrammatic.

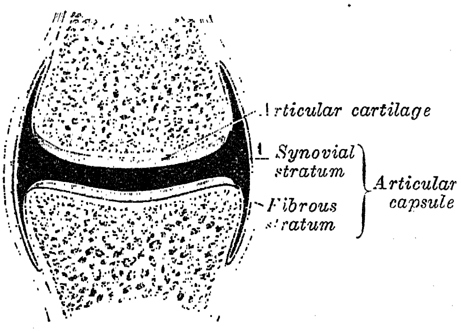
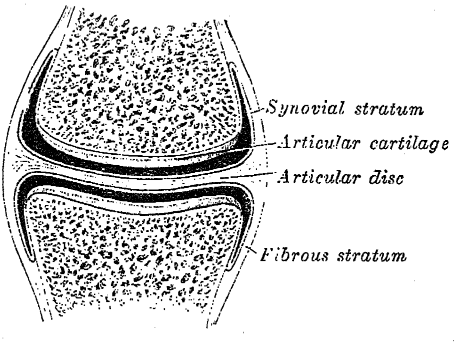


Fig. 466.—A section through a diarthrodial joint with an articular disc. Diagrammatic.



The joint may be completely divided by an *articular disc* (fig. 466), or incompletely by *menisci* (fig. 521); the periphery of such structures is continuous with the fibrous stratum of the articular capsule while their free surfaces are covered with the synovial stratum.

Diarthrodial joints are classified according to the kind of motion permitted in them. There are two varieties in which the movement is uni-axial; that

is to say, all movements take place around one axis. In one, the *ginglymus* or *hinge-joint*, this axis is, practically speaking, transverse; in the other, the *articulatio trochoidea* or *pivot-joint*, it is longitudinal. There are two varieties where the movement is bi-axial; these are the *articulatio ellipsoidea* or *condyloid joint* and the *articulatio sellaris* or *saddle-joint*. There is one form where the movement is poly-axial, the *articulatio sphæroidea* or *enarthrosis* (*ball-and-socket joint*); and finally there is the *arthrodia* or *gliding joint*.

Ginglymus or **hinge-joint.**—In this form the articular surfaces are moulded to each other in such a manner as to permit motion only in one plane. The articular surfaces are connected together by strong collateral ligaments, which form their chief bond of union. The best examples of ginglymus are the interphalangeal joints, and the joint between the humerus and ulna.

Trochoid articulation or **pivot-joint.**—Where the movement is limited to rotation, the joint is formed by a pivot turning within a ring, or a ring turning on a pivot, the ring being formed partly of bone, partly of ligament. In the proximal radio-ulnar articulation, the ring is formed by the radial notch of the ulna and the annular ligament; here, the head of the radius rotates within the ring. In the articulation of the dens of the epistropheus with the atlas, the ring is formed in front by the anterior arch, and behind by the transverse ligament, of the atlas; here, the ring rotates round the dens.

Condyloid articulation.—In this form of joint, an ovoid convex articular surface, or condyle, is received into an elliptical concavity in such a manner as to permit of flexion, extension, adduction, abduction, and circumduction, but no axial rotation. The radiocarpal joint is an example of this form of articulation.

Saddle-articulation.—In this variety the opposing surfaces are reciprocally concavoconvex, and the movements are the same as in the preceding form. The best example of the saddle-articulation is the carpometacarpal joint of the thumb.

Enarthrosis is a joint in which the distal bone is capable of motion around an indefinite number of axes, which have one common centre. It is formed by the reception of a globular head into a cup-like cavity, hence the name 'ball-and-socket.' Examples of this form of articulation are found in the hip- and shoulder-joints.

Arthrodia is a joint which admits of only gliding movement; it is formed by the apposition of plane, or nearly plane, surfaces, the amount of motion in such joints being limited by the ligaments or osseous processes surrounding the articulations. It is the form present in the joints between the articular processes of the vertebræ, and in most of the carpal and tarsal joints.

The Kinds of Movement permitted in Joints

The movements permitted in joints may be divided into four kinds: gliding and angular movements, circumduction, and rotation. Frequently these are more or less combined in the various joints, so as to produce an infinite variety, and it is seldom that only one kind of motion is found in any particular joint.

Gliding movement is the simplest kind of motion that can take place in a joint, one surface gliding over another without any angular or rotatory movement. It is common to all movable joints; but in some, as in most of the articulations of the carpus and tarsus, it is the only motion permitted. This movement is not confined to plane surfaces, but may take place between any two contiguous surfaces, of whatever form.

Angular movement occurs only between the long bones, and by it the angle between the two bones is increased or diminished. It may take place: (1) forwards and backwards, constituting flexion and extension; or (2) towards and from the median plane of the body, or, in the case of the fingers or toes, from the middle line of the hand or foot, constituting adduction and abduction. The strictly ginglymoid or hinge-joints admit of flexion and extension only. Abduction and adduction, combined with flexion and extension, are met with in the more movable joints.

Circumduction is that form of motion which takes place between the head of a bone and its articular cavity, when the bone is made to circumscribe a conical space;

the base of the cone is described by the distal end of the bone, the apex is in the articular cavity; this kind of motion is best seen in the shoulder- and hip-joints.

Rotation is a form of movement in which a bone moves round a longitudinal axis; the axis of rotation may lie in a separate bone, as in the case of the pivot formed by the dens of the epistropheus around which the atlas turns; or a bone may rotate around its own longitudinal axis, as in the rotation of the humerus at the shoulder-joint; or the axis of rotation may not be quite parallel to the long axis of the bone, as in the movement of the radius on the ulna during pronation and supination of the hand, where it is represented by a line connecting the centre of the head of the radius with the centre of the head of the ulna.

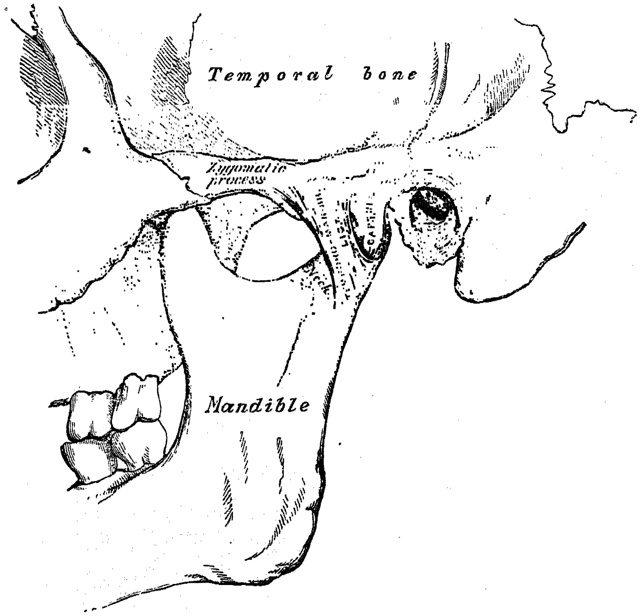
Applied Anatomy.—W. W. Keen points out how important it is 'that the surgeon should remember the ligamentous action of muscles in making passive motion—for instance, at the wrist after Colles's fracture. If the fingers be extended, the wrist can be flexed to a right angle. If, however, they be first flexed as in "making a fist," flexion at the wrist is quickly limited to from forty to fifty degrees in different persons, and is very painful beyond that point. Hence passive motion here should be made with the fingers extended. In the leg, when flexing the hip, the knee should be flexed.'

THE MANDIBULAR JOINT

The bony parts entering into the formation of the mandibular (temporomandibular) joint are: above, the articular tubercle and the anterior portion of the mandibular fossa of the temporal bone; below, the condyle of the mandible. An articular disc divides the joint into an upper and a lower cavity. The ligaments of the joint are the following:

The articular capsule.	Sphenomandibular.
Temporomandibular.	Stylomandibular.

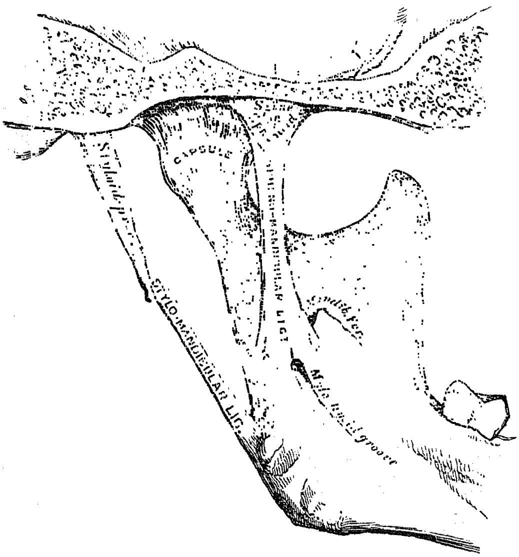
Fig. 467.—The left mandibular joint. Lateral aspect.



The **articular capsule** is a thin, loose envelope, attached, above, to the circumference of the mandibular fossa and the articular tubercle; below, to the neck of the mandible. The synovial stratum of the articular capsule is continued over the upper and lower surfaces of the articular disc.

The **temporomandibular ligament** (external lateral ligament) (fig. 467) consists of two short, narrow fasciculi, one in front of the other, attached, above, to the lateral surface of the zygomatic process of the temporal bone and to the tubercle on its lower border; below, to the lateral surface and posterior border of the neck of the mandible. It is broader above than below, and its fibres are directed obliquely downwards and backwards.

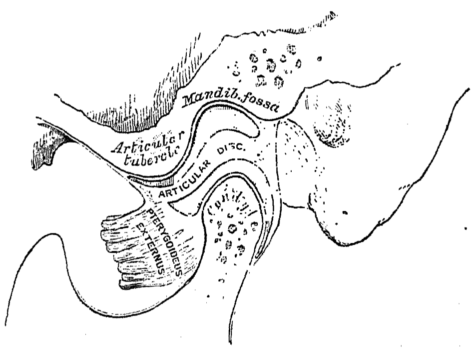
FIG. 468.—The left mandibular joint. Medial aspect.



The **sphenomandibular ligament** (fig. 468) is a flat, thin band which is attached above to the spina angularis of the sphenoidal bone, and, becoming broader as it descends, is fixed to the lingula of the mandibular foramen.* Its lateral surface is in relation, above, with the Pterygoideus externus; lower down, it is separated from the neck of the condyle by the internal maxillary vessels; still lower, the inferior alveolar vessels and nerve and a lobule of the parotid gland lie between it and the ramus of the mandible. Its medial surface is in relation with the Pterygoideus internus.

The **articular disc** (fig. 469) is a thin, oval plate, placed between the condyle of the mandible and the mandibular fossa; it divides the joint into two cavities. Its upper surface is concavoconvex from before backwards, to accommodate itself to the form of the mandibular fossa and the articular tubercle. Its under surface, in contact with the condyle, is concave. Its circumference is connected to the articular capsule, and in front to the tendon of the Pterygoideus externus. It is thicker at its periphery, especially behind, than at its centre, where it is sometimes perforated.

FIG. 469.—A sagittal section through the left mandibular joint.



The **stylomandibular ligament** (fig. 468) is a specialised band of the fascia colli (p. 448), which stretches from the apical part of the styloid process of the temporal bone to the angle and posterior border of the ramus of the mandible between the Masseter and Pterygoideus internus. It separates the parotid from the submaxillary gland, and from its deep surface some fibres of the Styloglossus take origin. Although classed among the ligaments of the mandibular joint, it can only be considered as accessory to it.

* J. Cameron (*Journal of Anatomy and Physiology*, vol. xlix.) points out that the cranial end of this ligament 'enters the inner extremity of the Glaserian fissure and whilst doing so is merely attached to the spine of the sphenoid by its inner edge.' He suggests that the attachment to the spina angularis of the sphenoidal bone is purely adventitious, and that the true morphological attachment is in reality to the lips of the fissure and also within the tympanic cavity, where a considerable proportion of the fibres are directly continuous with the fibrous layer of the membrana tympani. This intratympanic portion is usually described as the anterior ligament of the malleus. It forms a prominent band in a seven months' fœtus, and at this stage appears to be independent of the sphenoidal bone.

The *nerves* of the mandibular joint are derived from the auriculotemporal and masseteric branches of the mandibular nerve, the *arteries* from the superficial temporal branch of the external carotid artery, and from the internal maxillary artery.

Movements.—The mandible may be depressed and elevated, or carried forwards and backwards; a slight amount of side-to-side movement is also permitted. When the mouth is opened the body of the mandible is depressed, and the condyles and articular discs are pulled forwards on to the articular tubercles; in shutting the mouth the reverse action takes place. When the mandible is carried horizontally forwards, as in protruding the lower incisor teeth in front of the upper, the discs and the condyles glide forwards on the mandibular fossæ and articular tubercles. The grinding or chewing movement is produced by one condyle, with its disc, gliding alternately forwards and backwards, while the other condyle moves simultaneously in the opposite directions; at the same time the condyle undergoes a vertical rotation on the disc. One condyle advances and rotates, while the other recedes and rotates.

Muscles producing the movements:

Depression.—Digastrici, Mylohyoidei, Geniohyoidei and Pterygoidei externi.
Elevation.—Masseteres, Temporales and Pterygoidei interni.
Protrusion.—Pterygoidei interni et externi (both sides).
Retraction.—Temporales (posterior fibres).
Lateral movement.—Pterygoidei interni et externi (one side).

Applied Anatomy.—The mandible can be dislocated only in one direction—viz. forwards. When the mouth is open, the condyle is situated on the articular tubercle, and any sudden violence, or even a sudden muscular spasm, as during a convulsive yawn, may displace the condyle forwards into the infratemporal fossa. The displacement may be unilateral or bilateral. Reduction is accomplished by depressing the jaw with the thumbs placed on the last molar teeth, and at the same time elevating the chin. The downward pressure overcomes the spasm of the Masseter, Temporalis, and Pterygoideus internus, and elevation of the chin throws the condyle backwards; the above-mentioned muscles then draw the condyle back into its normal position.

In close relation to the condyle of the mandible are the external acoustic meatus and the tympanic cavity; any force, therefore, applied to the bone is liable to be attended with damage to these parts, or inflammation in the joint may extend to them. On the other hand inflammation of the tympanic cavity may involve the articulation and cause its destruction, thus leading to ankylosis of the joint.

THE ARTICULATIONS OF THE VERTEBRAL COLUMN

The vertebræ from the third cervical to the first sacral inclusive are articulated to one another by: (1) a series of amphiarthrodial joints between the vertebral bodies; and (2) a series of diarthrodial joints between the vertebral arches.

1. The Articulations of the Vertebral Bodies

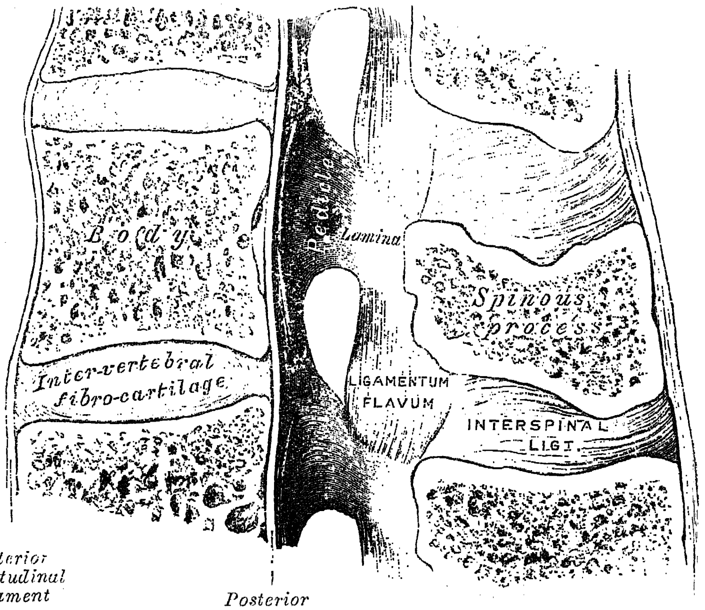
The amphiarthrodial articulations between the bodies of the vertebra allow of only slight movement between adjoining bones, but when this slight movement takes place in a considerable length of the vertebral column, the total range of movement is great. The vertebral bodies are united by anterior and posterior longitudinal ligaments, and by intervertebral fibrocartilages.

The **anterior longitudinal ligament** (fig. 470) is a strong band of fibres, which extends along the anterior surfaces of the bodies of the vertebræ. It is broader below than above, thicker and narrower in the thoracic than in the cervical and lumbar regions, and somewhat thicker and narrower opposite the bodies of the vertebræ than opposite the intervertebral fibrocartilages. It is attached above, to the pharyngeal tubercle of the occipital bone, whence it extends to the anterior tubercle of the atlas, then to the front of the body of the epistropheus, and is continued down as far as the upper

part of the front of the sacrum. It consists of dense longitudinal fibres, which are intimately adherent to the intervertebral fibrocartilages and the prominent margins of the vertebræ, but not to the middle parts of the vertebral bodies. In the latter situation the ligament is thick and fills up the concavities on the anterior surfaces, and makes the front of the vertebral column more even. It is composed of several layers of fibres, of which the most superficial are the longest and extend between four or five vertebræ. The intermediate fibres extend between two or three vertebræ, while the deepest reach from one vertebra to the next. At the sides of the bodies the ligament consists of a few short fibres which connect adjacent vertebræ.

The **posterior longitudinal ligament** (figs. 470, 471) is situated within the vertebral canal on the posterior surfaces of the bodies of the vertebræ. Above, it is attached to the body of the epistropheus, and is thence continued

FIG. 470.—A median sagittal section through a portion of the lumbar region of the vertebral column.

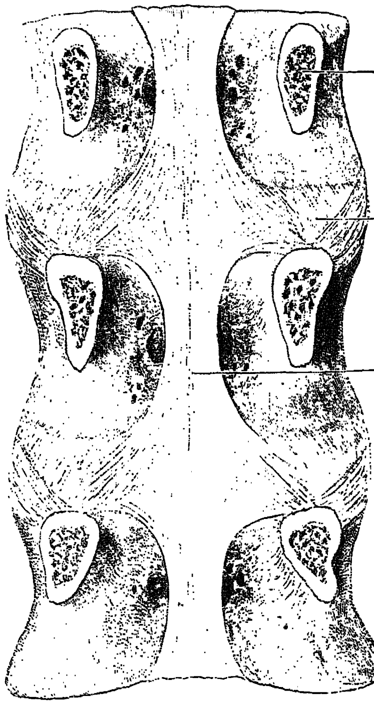


downwards to the sacrum; its upper end is intimately connected with the membrana tectoria which appears to be a continuation of it. It is broader above than below, and thicker in the thoracic than in the cervical and lumbar regions. In the situation of the intervertebral fibrocartilages and contiguous margins of the vertebræ, where the ligament is more intimately adherent, it is broad, and in the thoracic and lumbar regions presents a series of dentations with intervening concave margins; but it is narrow and thick over the centres of the bodies, from which it is separated by the basivertebral veins. This ligament is composed of smooth, shining fibres, denser and more compact than those of the anterior ligament, and consists of superficial layers occupying the interval between three or four vertebræ, and deeper layers which extend between adjacent vertebræ.

The **intervertebral fibrocartilages** (figs. 470, 471) are interposed between the adjacent surfaces of the bodies of the vertebræ, from the epistropheus to the sacrum, and form the chief bonds of connexion between the vertebræ. Their shape corresponds with that of the bodies between which they are placed. Their thickness varies in different regions of the column, and in different parts of the same fibrocartilage; they are thicker in front than behind in the cervical

and lumbar regions, and thus contribute to the anterior convexities of these parts of the column; while they are of nearly uniform thickness in the thoracic region, the anterior concavity of this part of the column being almost entirely due to the shape of the vertebral bodies. They are adherent, by their surfaces, to thin layers of hyaline cartilage which cover the upper and under surfaces of the bodies of the vertebræ; in the lower cervical vertebræ, however, small joints with articular capsules are occasionally present between the upper surfaces of the bodies and the margins of the fibrocartilages on either side. The intervertebral fibrocartilages are closely connected to the anterior and posterior longitudinal ligaments; in the thoracic region they are joined laterally, by means of the interarticular ligaments, to the heads of those ribs which articulate with two vertebræ. The intervertebral fibrocartilages constitute about one-fourth of the length of the vertebral column, exclusive of the first two vertebræ; but this amount is not equally distributed between the various bones, the cervical and lumbar portions having, in proportion to their length, a much greater amount than the thoracic region, with the result that these parts possess greater pliancy and freedom of movement.

Fig. 471.—The posterior longitudinal ligament of the vertebræ, in the lumbar region.



Structure of the intervertebral fibrocartilages.—Each is composed, at its circumference, of laminæ of fibrous tissue and fibrocartilage, forming the *annulus fibrosus*; and, at its centre, of a soft, pulpy, highly elastic substance, of a yellowish colour, which projects considerably above the surrounding level when the disc is divided horizontally. This pulpy substance (*nucleus pulposus*), especially well developed in the lumbar region, contains the remains of the notochord. The laminæ are arranged concentrically; the outermost consist of ordinary fibrous tissue, the others of white fibrocartilage. The laminæ are not quite vertical in their direction, those near the circumference being curved outwards and closely approximated; while those nearest the centre curve in the opposite direction, and are somewhat more widely separated. The fibres composing the laminæ are directed, for the most part, obliquely from above downwards, the fibres of adjacent laminæ passing in opposite directions and varying in every layer: so that the fibres of one layer are directed across those of another, like the limbs of the letter X. This laminar arrangement exists in about the outer half of each fibrocartilage. The pulpy substance presents no such arrangement, and consists of a fine fibrous matrix, containing angular cells united to form a reticular structure.

Applied Anatomy.—When an aneurysm presses on the vertebral column, the vertebral bodies are often deeply eroded by it, while the intervertebral fibrocartilages remain intact. The fibrocartilages are the first to be destroyed, however, in tuberculosis of the vertebral column, where, as not infrequently happens, the disease begins in a fibrocartilage, and spreads thence to the bodies of the two adjoining vertebræ.

2. The Articulations of the Vertebral Arches

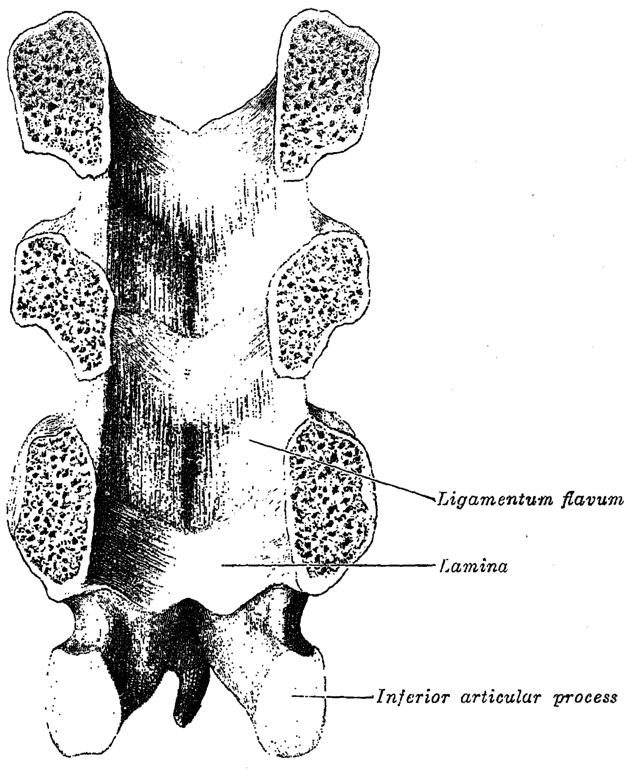
The joints between the articular processes of the vertebræ belong to the arthrodial variety and are enveloped by articular capsules ; the laminæ, spinous and transverse processes are connected by the following ligaments :

Ligamenta flava.	Ligamentum nuchæ.
Supraspinal.	Interspinal.
Intertransverse.	

The **articular capsules** are thin and loose, and are attached to the margins of the articular processes of adjacent vertebræ ; they are longer and looser in the cervical than in the thoracic and lumbar regions.

The **ligamenta flava** (figs. 470, 472) connect the laminæ of adjacent vertebræ, and are best seen from the interior of the vertebral canal. Their attachments

Fig. 472.—The ligamenta flava of the lumbar region. Anterior aspect.



extend from the articular capsules to the regions where the laminæ fuse to form the spinous processes ; here their posterior margins come into contact and are to a certain extent united, small intervals being left for the passage of vessels. The ligamenta flava consist of yellow elastic tissue, the fibres of which, almost perpendicular in direction, are attached to the anterior surface of the lamina above, some distance from its inferior margin, and to the posterior surface and upper margin of the lamina below. The ligaments are thin, but broad and long in the cervical region ; they are thicker in the thoracic region, and thickest in the lumbar region. Their elasticity helps to preserve the upright posture, and to assist the vertebral column in resuming it after flexion.

The **supraspinal ligament** (fig. 470) is a strong fibrous cord, which connects together the apices of the spinous processes from the seventh cervical vertebra to the sacrum ; fibrocartilage is developed in the ligament at its points of attachment to the tips of the spinous processes. It is thicker and broader

in the lumbar than in the thoracic region, and intimately blended in both situations with the neighbouring fascia. The most superficial fibres of this ligament extend over three or four vertebræ; those more deeply seated pass between two or three vertebræ; while the deepest connect the spinous processes of neighbouring vertebræ. Between the spinous processes it is continuous with the interspinal ligaments. Between the spinous process of the seventh cervical vertebra and the external occipital protuberance its place is taken by the ligamentum nuchæ.

The **ligamentum nuchæ** is a fibrous membrane, which, in the neck, is homologous with the supraspinal ligament of the thoracic and lumbar vertebræ. It extends from the external protuberance and median nuchal line of the occipital bone to the spinous process of the seventh cervical vertebra. From its anterior border a fibrous lamina is given off, which is attached to the posterior tubercle of the atlas, and to the spinous processes of the cervical vertebræ, and forms a septum between the muscles of the two sides of the neck. In man it is the representative of an important elastic ligament, which, in some of the lower animals, serves to sustain the weight of the head.

The **interspinal ligaments** (fig. 470), thin and membranous, connect adjoining spinous processes, and their attachments extend from the root to the apex of each process. They meet the ligamenta flava in front and the supraspinal ligament behind. They are narrow and elongated in the thoracic region; broader, thicker, and quadrilateral in form in the lumbar region; and only slightly developed in the neck.

The **intertransverse ligaments** are interposed between the transverse processes. In the cervical region they consist of a few irregular, scattered fibres; in the thoracic region they are rounded cords intimately connected with the deep muscles of the back; in the lumbar region they are thin and membranous.

3. The Sacrococcygeal Symphysis

This articulation is an amphiarthrodial joint, between the apex of the sacrum and the base of the coccyx, the bones being united by anterior, posterior and lateral sacrococcygeal ligaments, and by a disc of fibrocartilage.

The **anterior sacrococcygeal ligament** (fig. 501) consists of a few irregular fibres, which descend from the anterior surface of the sacrum to the front of the coccyx, blending with the periosteum.

The **posterior sacrococcygeal ligament** is a flat band, which arises from the margin of the lower orifice of the sacral canal, and descends to be inserted into the posterior surface of the coccyx. This ligament completes the lower part of the sacral canal, and is divisible into a short *deep* and a longer *superficial* part.

A **lateral sacrococcygeal ligament** exists on either side and connects the transverse process of the coccyx to the inferior lateral angle of the sacrum; it completes the foramen for the fifth sacral nerve.

A thin disc of **fibrocartilage** is interposed between the contiguous surfaces of the sacrum and coccyx; it is somewhat thicker in front and behind than at the sides. Occasionally the coccyx is freely movable on the sacrum; in such cases an articular capsule lined with a synovial stratum is present.

The different segments of the coccyx are connected together by the extension downwards of the anterior and posterior sacrococcygeal ligaments, thin annular discs of fibrocartilage being interposed between the segments. In the adult male, all the pieces become ossified together at a comparatively early period; but in the female, this does not commonly occur until a later period of life. At a more advanced age the joint between the sacrum and coccyx is obliterated.

Backward and forward movements take place between the sacrum and coccyx; their extent increases during pregnancy.

Movements.—The movements permitted in the vertebral column are: flexion, extension, lateral movement, circumduction, and rotation.

In *flexion*, or movement forwards, the anterior longitudinal ligament is relaxed and the anterior parts of the intervertebral fibrocartilages are compressed; while the posterior longitudinal ligament, the ligamenta flava, and the interspinal and

supraspinal ligaments are stretched, as well as the posterior fibres of the intervertebral fibrocartilages. The interspaces between the laminæ are widened, and the inferior articular processes glide upwards upon the superior articular processes of the subjacent vertebræ. Flexion is the most extensive of all the movements of the vertebral column, and is freest in the lumbar region.

In *extension*, or movement backwards, an exactly opposite disposition of the parts takes place. This movement is limited by the anterior longitudinal ligament, and by the approximation of the spinous processes. It is freest in the cervical region.

In *lateral movements*, the sides of the intervertebral fibrocartilages are compressed, the extent of motion being limited by the resistance offered by the surrounding ligaments. Lateral movements may take place in any part of the column, but are freest in the cervical and lumbar regions.

Circumduction is very limited, and is merely a succession of the preceding movements.

Rotation is produced by the twisting of the intervertebral fibrocartilages; this, although only slight between any two vertebræ, allows of a considerable extent of movement when it takes place in the whole length of the column, the front of the upper part of the column being turned to one or other side. This movement occurs to a slight extent in the cervical region, is freer in the upper part of the thoracic region, and absent in the lumbar region.

The extent and variety of the movements are influenced by the shape and direction of the articular surfaces. In the *cervical* region the upward inclination of the superior articular surfaces allows of free flexion and extension. Extension can be carried farther than flexion; at the upper end of the region it is checked by the locking of the posterior edges of the superior atlantal facets in the condyloid fossæ of the occipital bone; at the lower end it is limited by a mechanism whereby the inferior articular processes of the seventh cervical vertebra slip into grooves behind and below the superior articular processes of the first thoracic. Flexion is arrested just beyond the point where the cervical convexity is straightened; the movement is checked by the apposition of the projecting lower lips of the bodies of the vertebræ with the shelving surfaces on the bodies of the subjacent vertebræ. Lateral flexion and rotation are free in the cervical region, and are always combined; the upward and medial inclinations of the superior articular surfaces impart a rotatory movement during lateral flexion. In the *thoracic* region, notably in its upper part, all the movements are limited in order to reduce interference with respiration to a minimum. The almost complete absence of an upward inclination of the superior articular surfaces prohibits any marked flexion, while extension is checked by the contact of the inferior articular margins with the laminæ, and the contact of the spinous processes with one another. Rotation is free in the thoracic region: the superior articular processes are segments of a cylinder whose axis is in the mid-ventral line of the vertebral bodies. The direction of the articular facets would allow of free lateral flexion, but this movement is considerably limited in the upper part of the region by the resistance of the ribs and sternum. In the *lumbar* region flexion and extension are free. The inferior articular facets are not in close apposition with the superior facets of the subjacent vertebræ, and on this account a considerable amount of lateral flexion is permitted. For the same reason a slight amount of rotation can be carried out, but this is so soon checked by the interlocking of the articular surfaces that it is negligible.

Muscles producing the movements.—The vertebral column may be moved either by (*a*) muscles attached to it and acting directly on it, or by (*b*) muscles attached to other bones and acting indirectly on the column.

a. Muscles acting *directly* on the vertebral column.

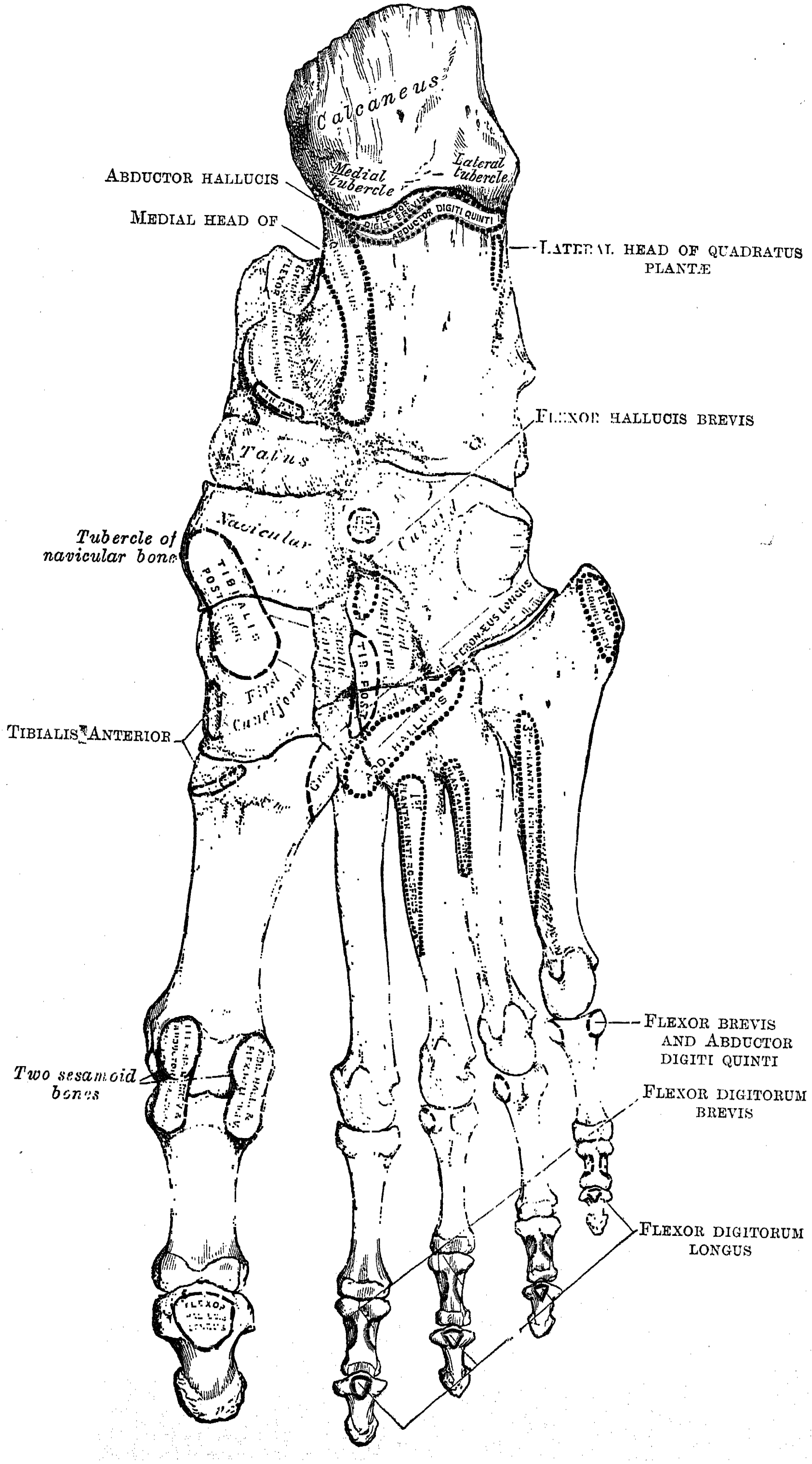
Flexion.—Longus colli, Scaleni, Quadratus lumborum, Psoas major and Psoas minor.

Extension.—Interspinales, Multifidus, Spinales, Semispinales dorsi et cervicis, Iliocostalis cervicis, Longissimi dorsi et cervicis and Splenius cervicis.

Lateral flexion.—Intertransversarii, Multifidus, Iliocostalis cervicis, Longissimus cervicis, Splenius cervicis, Levatores costarum, Longus colli, Scaleni, Quadratus lumborum and Psoas major.

Rotation.—Rotatores, Multifidus, Splenius cervicis, Semispinales dorsi et cervicis, Levatores costarum and Longus colli.

FIG. 440.—The bones of the right foot. Plantar aspect.



The transverse ligament of the atlas (figs. 475 to 477) is a thick, strong band, which arches across the ring of the atlas, and retains the dens

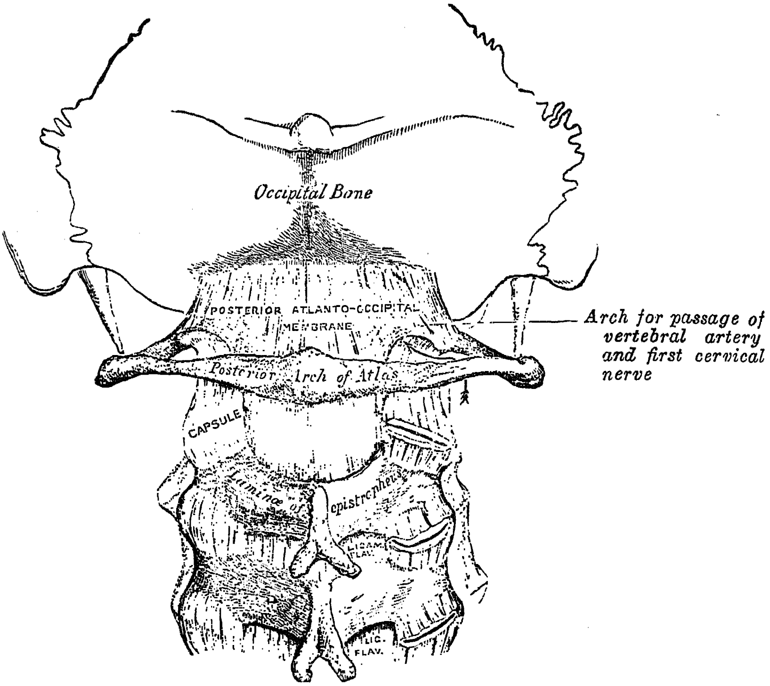


Fig. 474.—The posterior atlanto-occipital membrane.

of the epistropheus in contact with the anterior arch. It is concave in front, convex behind, broader in the middle than at the ends, and firmly attached on either side to a small tubercle on the medial surface of the lateral mass of the atlas. As it crosses the dens, a small fasciculus (*crus superius*) is prolonged

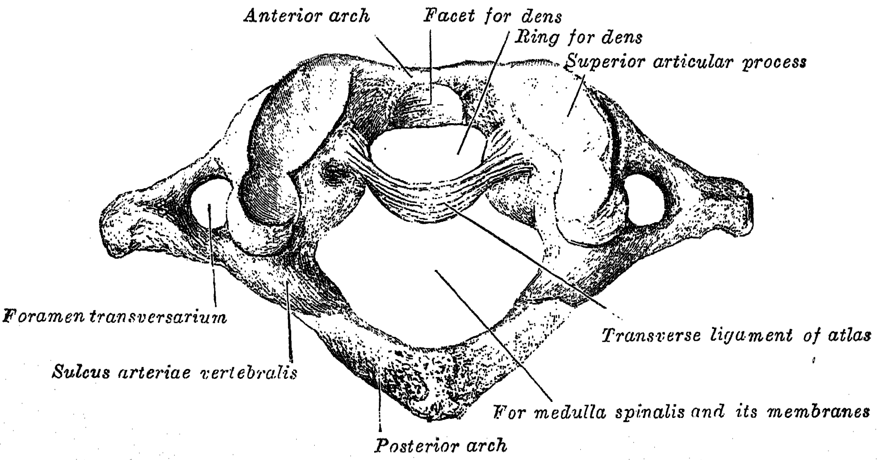


Fig. 475.—The atlas vertebra, with the transverse ligament.

upwards, and another (*crus inferius*) downwards, from the superficial or posterior fibres of the ligament. The crus superius is attached to the upper surface of the

FIG. 476.—The membrana tectoria, and the transverse and alar ligaments. The crus superius of the transverse ligament is drawn to one side.

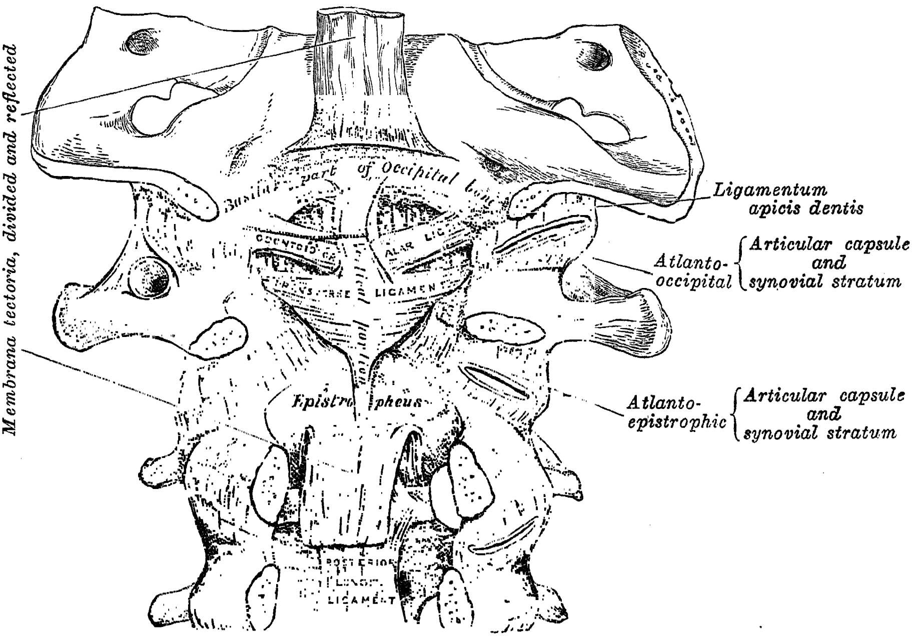
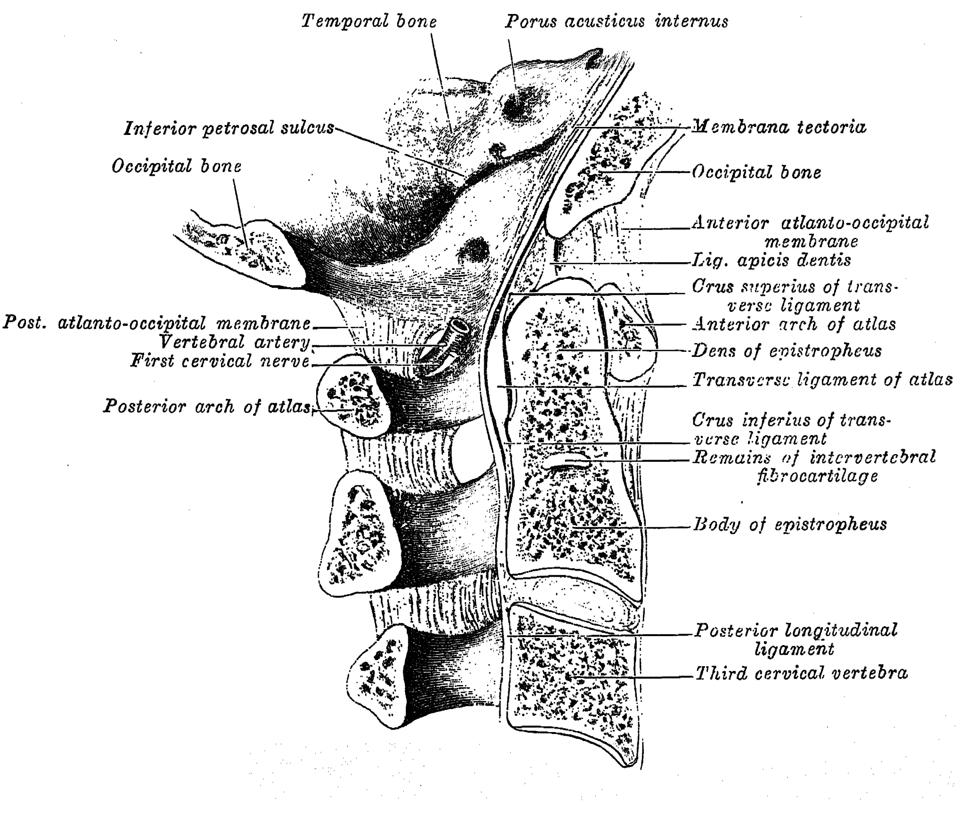


FIG. 477.—A median sagittal section through the occipital bone and first three cervical vertebræ.



basilar part of the occipital bone between the ligamentum apicis dentis and the membrana tectoria; the crus inferius is attached to the posterior surface of the body of the epistropheus; hence the whole ligament is named the *ligamentum cruciatum atlantis*. The transverse ligament divides the ring of the atlas into two unequal parts: of these, the posterior and larger surrounds the medulla spinalis and its membranes and the spinal parts of the accessory nerves; the anterior and smaller contains the dens. The neck of the dens is constricted where it is embraced posteriorly by the transverse ligament, so that this ligament suffices to retain the process in position after all the others have been divided.

The joint-cavity between the dens and the transverse ligament is often continuous with those of the atlanto-occipital articulations.

Movements.—This articulation with its three joints allows the rotation of the atlas (and, with it, the skull) upon the epistropheus, the extent of rotation being limited by the alar ligaments (p. 367).

The opposed articular surfaces of the atlas and epistropheus are not reciprocally curved; both are convex in their long axes. When, therefore, the upper facet glides forwards on the lower it also descends; the fibres of the articular capsule are relaxed in a vertical direction, and will then permit of movement in an anteroposterior direction. By this means a shorter capsule suffices and the strength of the joint is materially increased.

Muscles producing the movements.—The principal muscles by which these movements are produced are the Sternocleidomastoideus and Semispinalis capitis of one side, acting with the Longus capitis, Splenius, Longissimus capitis, Rectus capitis posterior major, and Obliquus capitis inferior of the other side.

THE ARTICULATIONS OF THE VERTEBRAL COLUMN WITH THE CRANIUM

The ligaments connecting the vertebral column with the cranium may be divided into two sets; those uniting the atlas with the occipital bone, and those connecting the epistropheus with the occipital bone.

1. The Articulation of the Atlas with the Occipital Bone

The articulation between the atlas and the occipital bone consists of a pair of condyloid joints. The ligaments connecting the bones are:

Two articular capsules.	Anterior and posterior atlanto-occipital membranes.

The **articular capsules** surround the condyles of the occipital bone and the superior articular processes of the atlas: they are thin and loose. Their lateral portions are directed obliquely upwards and medialwards, and are reinforced by bundles of fibres, which are attached above to the jugular processes of the occipital bone, and below to the bases of the transverse processes of the atlas.

The atlanto-occipital joints frequently communicate with the joint between the dens and the transverse ligament of the atlas.

The **anterior atlanto-occipital membrane** (fig. 473) is broad, and composed of densely woven fibres which pass between the anterior margin of the foramen magnum above, and the upper border of the anterior arch of the atlas below; laterally, it is continuous with the articular capsules; in front, it is strengthened in the middle line by the continuation of the anterior longitudinal ligament, a strong, rounded cord, which connects the basilar part of the occipital bone to the tubercle on the anterior arch of the atlas.

The **posterior atlanto-occipital membrane** (fig. 474), broad but thin, is connected, above, to the posterior margin of the foramen magnum; below, to the upper border of the posterior arch of the atlas. On either side it arches over the groove for the vertebral artery, and with this groove bounds an opening for the entrance of the artery and the exit of the first cervical nerve. The free border of the membrane, arching over the artery and nerve, is sometimes ossified.

Movements.—The movements permitted in this joint are (*a*) flexion and extension, which give rise to the ordinary forward and backward nodding of the head, and (*b*) slight lateral motion to one or other side.

Muscles producing the movements :

Flexion.—Longus capitis and Rectus capitis anterior.

Extension.—Recti capitis posteriores major et minor, Obliquus superior, Semispinalis capitis, Splenius capitis, Sternocleidomastoideus and Trapezius (upper fibres).

Lateral flexion.—Rectus capitis lateralis, Semispinalis capitis, Splenius capitis, Sternocleidomastoideus and Trapezius (upper fibres).

2. The Ligaments connecting the Epistropheus with the Occipital Bone

Membrana tectoria. Two alar. Ligamentum apicis dentis.

The **membrana tectoria** (occipito-axial ligament) (figs. 476, 477) is situated within the vertebral canal. It is a broad, strong band, which covers the dens and its ligaments, and appears to be a prolongation upwards of the posterior longitudinal ligament of the vertebral column. It is fixed, below, to the posterior surface of the body of the epistropheus, and, expanding as it ascends, is attached above to the upper surface of the basilar part of the occipital bone, in front of the foramen magnum, blending with the cranial dura mater.

The **alar ligaments** (odontoid ligaments) (fig. 476) are two strong, rounded cords, which arise one on either side of the upper part of the dens, and passing obliquely upwards and lateralwards, are inserted into rough impressions on the medial sides of the condyles of the occipital bone. The alar ligaments limit rotation of the cranium and therefore receive the name of *check ligaments*.

Between the alar ligaments is the **ligamentum apicis dentis** (fig. 477) which extends from the tip of the dens to the anterior margin of the foramen magnum, being intimately blended with the deep portion of the anterior atlanto-occipital membrane and with the superior crus of the transverse ligament of the atlas. It is regarded as a rudimentary intervertebral fibrocartilage, and traces of the notochord may persist in it.

In addition to the ligaments which unite the atlas and epistropheus to the skull, it must be remembered that the ligamentum nuchæ (p. 361) connects the cervical vertebræ with the cranium.

Applied Anatomy.—The ligaments of the vertebral column are so strong, and the bones so interlocked by the arrangement of their articulating processes, that dislocation is very uncommon, and, except in the upper part of the neck, rarely occurs unless accompanied by fracture. Dislocation of the occipital bone from the atlas has been recorded only in one or two cases; but dislocation of the atlas from the epistropheus, with rupture of the transverse ligament of the atlas, is much more common; it is the mode in which death is produced in many cases of execution by hanging. Hanging may however produce a fracture through the epistropheus, or a separation through the fibrocartilage between the epistropheus and the third cervical vertebra. Below the third cervical vertebra, dislocation without fracture occasionally takes place.

THE COSTOVERTEBRAL ARTICULATIONS

The articulations of the ribs with the vertebral column may be divided into two sets, one connecting the heads of the ribs with the bodies of the vertebræ, another uniting the necks and tubercles of the ribs with the transverse processes.

1. The Articulations of the Heads of the Ribs (fig. 478)

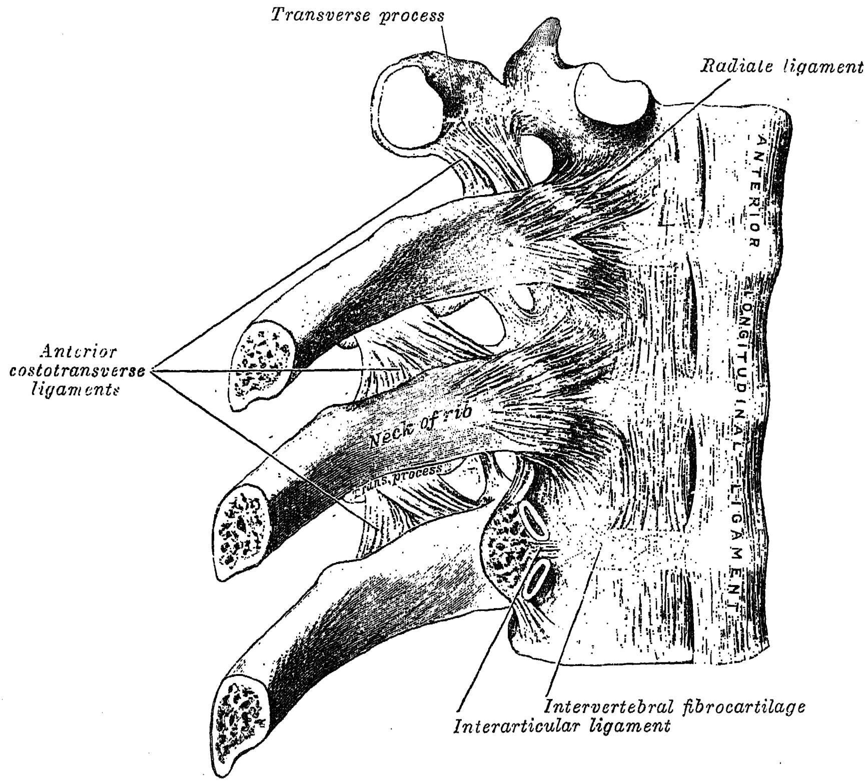
These articulations, sometimes named the *costocentral*, constitute a series of arthrodial joints. They are formed by the articulation of the heads of the typical ribs with the facets on the contiguous margins of the bodies of the thoracic vertebræ and with the intervertebral fibrocartilages between them; the first,

tenth, eleventh, and twelfth ribs each articulate with a single vertebra. The ligaments of the joints are :

The articular capsules. Radiate.
Interarticular.

In the articulations of the heads of the ribs from the second to the ninth inclusive, two articular capsules are present, since each of these joints is subdivided by an interarticular ligament. The **articular capsules** connect the heads of the ribs with the circumferences of the articular cavities formed by the intervertebral fibrocartilages and the adjacent vertebræ. Some of their upper fibres pass through the intervertebral foramen to the back of the intervertebral fibrocartilage, while the posterior fibres are continuous with the ligament of the neck of the rib.

FIG. 478.—The costovertebral articulations. Right antero-lateral aspect.



The **radiate ligament** (stellate ligament) connects the anterior part of the head of each rib with the sides of the bodies of two vertebræ, and the intervertebral fibrocartilage between them. It is attached to the anterior part of the head of the rib, just beyond the articular surface. The superior fibres ascend, and are connected with the body of the vertebra above ; the inferior fibres descend to the body of the vertebra below ; the middle fibres, the smallest and least distinct, are horizontal and attached to the intervertebral fibrocartilage.

In the articulation of the first rib, the radiate ligament is attached to the body of the last cervical vertebra, as well as to that of the first thoracic. In the articulations of the tenth, eleventh, and twelfth ribs, each of which articulates with a single vertebra, the radiate ligament is connected to the vertebra with which the rib articulates, and also to the vertebra immediately above it.

The **interarticular ligament** is situated in the interior of the joint. It consists of a short band of fibres, flattened from above downwards, attached, laterally to the crest separating the two articular facets on the head of the rib, and medially to the intervertebral fibrocartilage ; it divides the joint

into two cavities and its upper and lower surfaces are covered with the synovial strata of the articular capsules. In the joints of the first, tenth, eleventh, and twelfth ribs, interarticular ligaments do not exist; consequently, there is but one cavity in each of these articulations. The interarticular ligament is the homologue of the *ligamentum conjugale* which is present in some mammals, and unites the heads of opposite ribs across the back of the intervertebral fibrocartilage.

2. The Costotransverse Articulations (fig. 479)

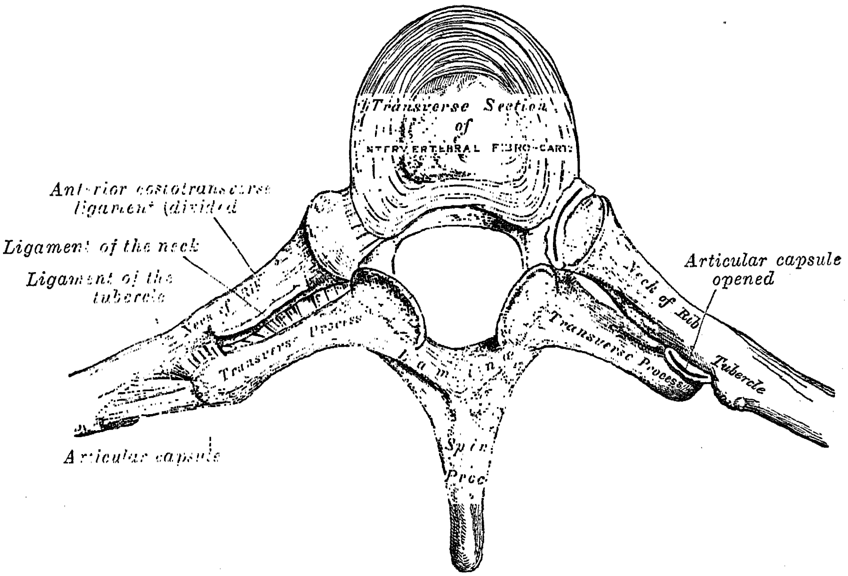
The articular portion of the tubercle of a rib forms an arthrodial joint with the transverse process of the lower of the two vertebræ to which the head of the rib is fixed. In the eleventh and twelfth ribs this articulation is wanting.

The ligaments of the joint are:

The articular capsule.
Anterior and posterior costotransverse.
Ligament of the neck of the rib.
Ligament of the tubercle of the rib.

The **articular capsule** is a thin membrane attached to the circumference of the articular surfaces, and lined with a synovial stratum.

Fig. 479.—The costotransverse articulations. Superior aspect.



The **anterior costotransverse ligament** is attached below to the crest on the upper border of the neck of the rib, and passes obliquely upwards and lateralwards to the lower border of the transverse process immediately above. The first rib has no anterior costotransverse ligament. The neck of the twelfth rib is connected to the base of the transverse process of the first lumbar vertebra by a band of fibres, named the *lumbocostal ligament*; it is in series with the anterior costotransverse ligaments.

The **posterior costotransverse ligament** is a feeble band which is attached below to the neck of the rib, behind and medial to the anterior costotransverse ligament; it passes upwards and medialwards to the base of the transverse process and the lateral border of the inferior articular process of the vertebra above.

The **ligament of the neck of the rib** (interosseous costotransverse ligament) consists of short but strong fibres, connecting the rough surface on the back of the neck of the rib with the anterior surface of the adjacent transverse process. A rudimentary ligament may be present at the eleventh and twelfth ribs.

The **ligament of the tubercle of the rib** is a short, thick, strong fasciculus, which passes obliquely from the apex of the transverse process to the rough non-articular portion of the tubercle of the rib. The ligaments attached to the upper ribs ascend from the transverse processes; they are shorter and more oblique than those attached to the lower ribs, which descend slightly.

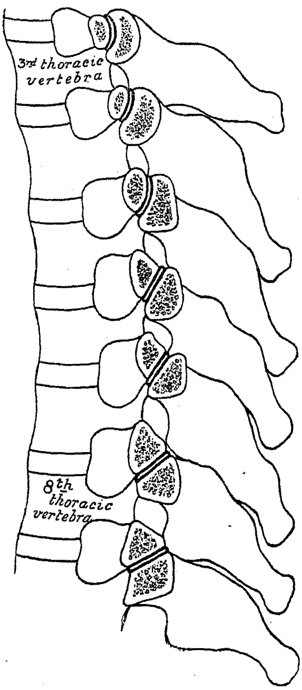


FIG. 480.—A section through the costotransverse joints from the third to the ninth inclusive. Contrast the concave facets on the upper with the flattened facets on the lower transverse processes.

Movements.—The heads of the ribs are so closely connected to the bodies of the vertebræ by the radiate and interarticular ligaments that only slight gliding movements of the articular surfaces on one another can take place. Similarly, the strong ligaments binding the necks and tubercles of the ribs to the transverse processes limit the movements of the costotransverse joints to slight gliding, the nature of which is determined by the shape and direction of the articular surfaces (fig. 480). The articular surfaces on the tubercles of the upper six ribs are oval in shape and convex from above downwards; they fit into corresponding concavities on the anterior surfaces of the transverse processes, so that upward and downward movements of the tubercles are associated with rotation of the rib-neck on its long axis. On the seventh, eighth, ninth, and tenth ribs the articular surfaces on the tubercles are flat, and are directed obliquely downwards, medialwards, and backwards. The surfaces with which they articulate are placed on the upper margins of the transverse processes; when, therefore, the tubercles are drawn up they are at the same time carried backwards and medialwards. The two joints, costocentral and costotransverse, move simultaneously and in the same directions, the total effect being that the neck of the rib moves as if on a single joint, of which the costocentral and costotransverse articulations form the ends. In the upper six ribs the neck of the rib moves but slightly upwards and downwards; its chief movement is one of rotation round its own long axis, rotation backwards being associated with depression, rotation forwards with elevation. In the seventh, eighth, ninth, and tenth ribs the neck of the rib moves upwards, backwards, and medialwards, or downwards, forwards, and lateralwards; very slight rotation accompanies these movements.

Muscles producing the movements.—These are discussed with the mechanism of respiration (p. 468).

THE STERNOCOSTAL ARTICULATIONS (fig. 481)

The cartilages of the true ribs, with the exception of the first, articulate with the sternum by arthrodial joints. The cartilage of the first rib is directly united with the sternum, and the joint between this rib and the sternum is a synchondrosis.

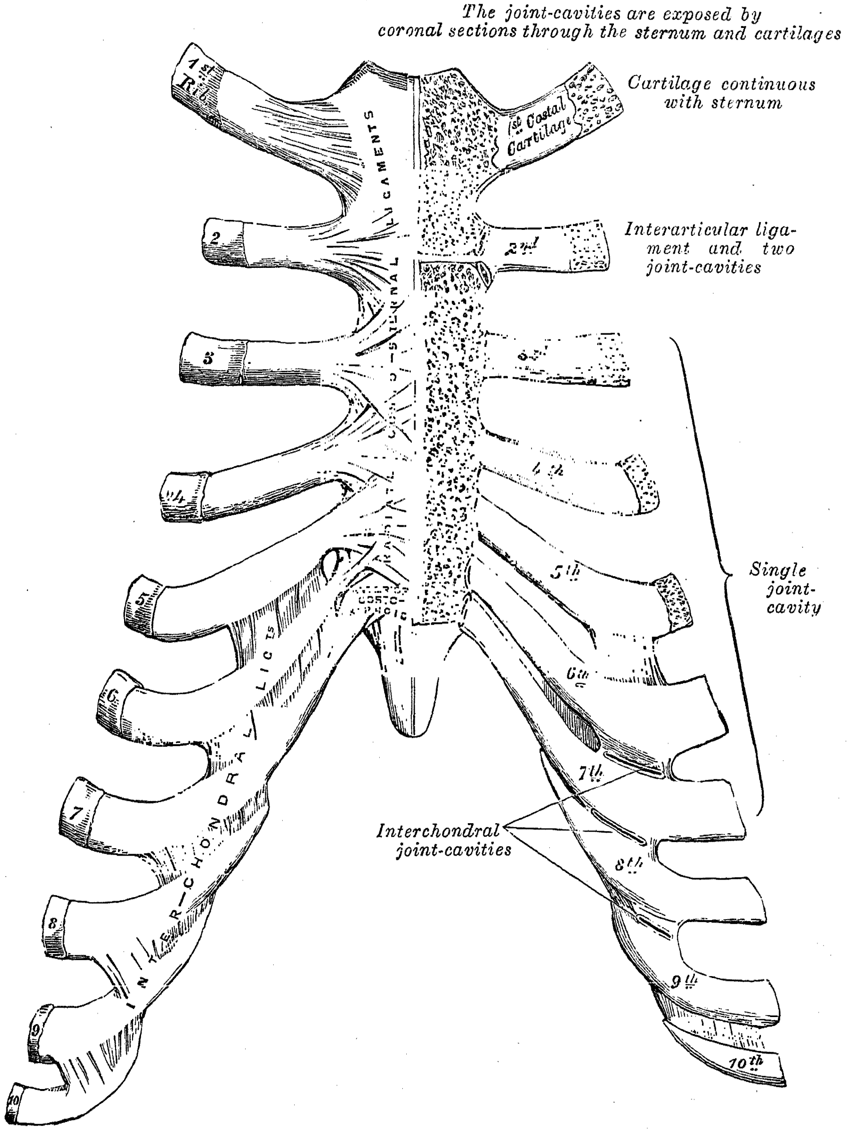
The ligaments of the arthrodial joints are:

The articular capsules.	Interarticular sternocostal.
Radiate sternocostal.	Costoxiphoid.

The **articular capsules** surround the joints between the sternum and the cartilages of the ribs from the second to the seventh inclusive. They are very thin, intimately blended with the radiate sternocostal ligaments, and strengthened at the upper and lower parts of the articulations by a few fibres, which connect the cartilages to the side of the sternum.

The **radiate sternocostal ligaments** are broad, thin membranous bands which radiate from the front and back of the sternal ends of the cartilages of the true ribs to the anterior and posterior surfaces of the sternum. Their superficial fibres intermingle with the fibres of the ligaments above and below them, with those of the opposite side, and on the front of the sternum with

FIG. 481.—The sternocostal and interchondral articulations. Anterior aspect.



the tendinous fibres of origin of the Pectoralis major, forming a thick fibrous membrane (*membrana sterni*) which envelops the bone, and is more distinct at its lower than at its upper part.

The **interarticular sternocostal ligaments** are found constantly only between the second costal cartilages and the sternum. The cartilage of the *second rib* is connected with the sternum by means of an interarticular ligament, attached laterally to the cartilage of the rib, and medially to the fibrocartilage which unites the manubrium and body of the sternum. Occasionally the cartilage of the *third rib* is connected with the first and second pieces of the body

of the sternum by an interarticular ligament. Still more rarely, similar ligaments are found in the other four joints of the series. In the lower two an interarticular ligament sometimes obliterates the joint-cavity, so as to convert the articulation into an amphiarthrosis. After middle life the articular surfaces lose their polish, become roughened, and the synovial strata apparently disappear. In old age, the cartilages of most of the ribs become continuous with the sternum, and the joint-cavities are consequently obliterated.

The **costoxiphoid ligaments** connect the anterior and posterior surfaces of the seventh costal cartilage, and sometimes those of the sixth, to the front and back of the xiphoid process. They vary in length and breadth in different subjects; those on the back of the joint are less distinct than those in front.

Movements.—Slight gliding movements are permitted in the sternocostal articulations.

The Interchondral Articulations (fig. 481)

The contiguous borders of the sixth and seventh, the seventh and eighth, and the eighth and ninth, costal cartilages articulate with each other by small smooth, oblong facets. Each articulation is enclosed in a thin *articular capsule*, lined with a synovial stratum and strengthened laterally and medially by *interchondral ligaments* which pass from one cartilage to the other. Sometimes the fifth costal cartilages, more rarely the ninth, articulate by their lower borders with the adjoining cartilages by small oval facets; more frequently the connexion is by a few ligamentous fibres.

The Costochondral Articulations

The lateral end of each costal cartilage is received into a depression in the sternal end of the rib, and the two are enveloped by the periosteum.

The Articulation of the Manubrium with the Body of the Sternum

In the majority of cases the joint between the manubrium and the body of the sternum is a symphysis, the bony surfaces being coated with cartilage and connected by a disc of fibrocartilage which tends to ossify in advanced life. In rather more than thirty per cent. of cases the central part of the disc undergoes absorption and the joint is converted into a diarthrodial one. The two segments of the bone are also connected by the membrana sterni.

The Mechanism of the Thorax

Each rib possesses its own range and variety of movements, but the movements of all are combined in the respiratory excursions of the thorax. Each rib may be regarded as a lever, the fulcrum of which is situated immediately outside the costotransverse articulation, so that when the body of the rib is elevated the neck is depressed and *vice versa*; from the disproportion in length of the arms of the lever a slight movement at the vertebral end of the rib is greatly magnified at the anterior extremity.

The anterior ends of the ribs lie on a lower plane than the posterior; when therefore the body of the rib is elevated the anterior extremity is also thrust forwards. Again, the middle of the body of the rib lies in a plane below that passing through the two extremities, so that when the body is elevated relatively to its ends it is at the same time carried outwards from the median plane of the thorax; further, each rib forms the segment of a curve which is greater than that of the rib immediately above. Therefore the elevation of a rib increases the transverse diameter of the thorax in the plane to which it is raised. The modifications of the rib movements at their vertebral ends have already been described (p. 370). Further modifications result from the attachments of their anterior extremities, and it is convenient therefore to consider separately the movements of the ribs of the three groups—vertebrosternal, vertebrochondral, and vertebral.

Vertebrosternal ribs (figs. 482, 483).—The first rib differs from the others of this group in that its attachment to the sternum is a rigid one; this is counterbalanced to some extent by the fact that its head possesses no interarticular ligament, and is therefore more movable. The first pair of ribs with the manubrium sterni move as a single piece, the anterior portion being elevated by rotatory movements at the vertebral extremities. In normal quiet respiration the movement of this arc is practically *nil*; when it does occur the anterior part is raised and carried forwards, increasing the anteroposterior and transverse diameters of this region of the chest. The movement of the second rib is also slight in normal respiration, as its anterior extremity is fixed to the manubrium, and prevented therefore from moving upwards. The sternocostal articulation, however, allows the middle of the body of the rib to be drawn up, and in this way the transverse thoracic diameter is increased. Elevation of the third, fourth, fifth,

Fig. 482.—A lateral view of the first and the seventh ribs in position, showing the movements of the sternum and ribs in, A, ordinary expiration; B, quiet inspiration; C, deep inspiration.

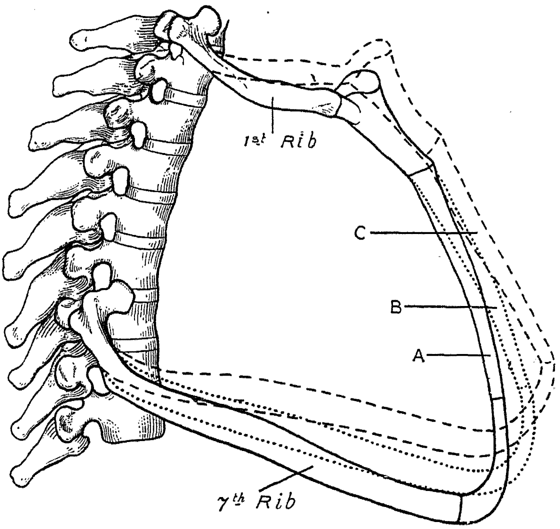


Fig. 483.—A diagram showing the axis of movement (AB and CD) of a vertebrosternal rib. The interrupted lines indicate the position of the rib in inspiration.

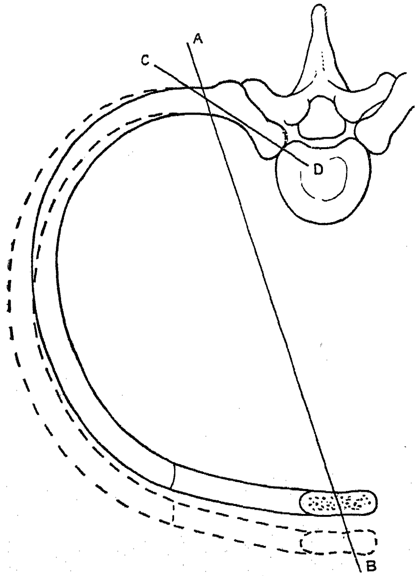
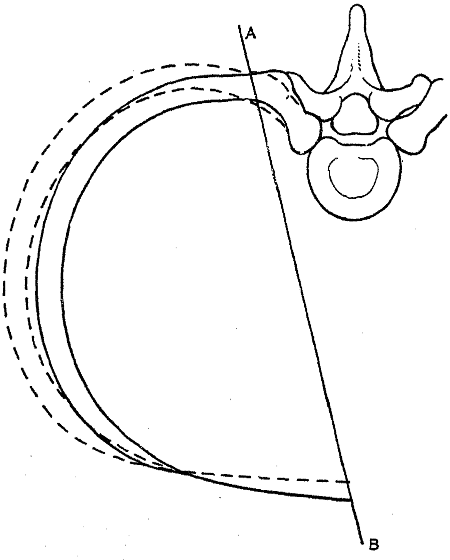


Fig. 484.—A diagram showing the axes of movement (AB) of a vertebrochondral rib. The interrupted lines indicate the position of the rib in inspiration.



and sixth ribs raises and thrusts forwards their anterior extremities, the greater part of the movement being effected by the rotation of the rib-neck backwards.

The thrust of the anterior extremities carries forwards and upwards the body of the sternum, which moves on the joint between it and the manubrium, and thus the anteroposterior thoracic diameter is increased. This movement is, however, soon arrested, and the elevating force is then expended in raising the middle part of the body of the rib and everting its lower border; at the same time the costochondral angle is opened out. By these latter movements a considerable increase in the transverse diameter of the thorax is effected.

Vertebrochondral ribs (fig. 484).—The seventh rib is included with this group, as it conforms more closely to their type. While the movements of these ribs assist in enlarging the thorax for respiratory purposes, they are also concerned in increasing the upper abdominal space for viscera displaced by the action of the Diaphragm. The costal cartilages articulate with one another, so that each pushes up that above it, the final thrust being directed to pushing forwards and upwards the lower end of the body of the sternum. The amount of elevation of the anterior extremities is limited on account of the very slight rotation of the rib-neck. Elevation of the shaft is accompanied by an outward and backward movement; the outward movement everts the anterior end of the rib and opens up the subcostal angle, while the backward movement pulls back the anterior extremity and counteracts the forward thrust due to its elevation; this latter is most noticeable in the lower ribs, which are the shortest. The total result is a considerable increase in the transverse and a diminution in the median anteroposterior diameter of the upper part of the abdomen; at the same time, however, the lateral anteroposterior diameters of the abdomen are increased.

Vertebral ribs.—Since these ribs have free anterior extremities and only costocentral articulations with no interarticular ligaments, they are capable of slight movements in all directions. When the other ribs are elevated these are depressed and fixed to form points of action for the Diaphragm.

Muscles producing the movements.—These are discussed with the mechanism of respiration (p. 468).

THE ARTICULATIONS OF THE UPPER EXTREMITY

The articulations of the upper extremity comprise the following:

I. The sternoclavicular.
II. The acromioclavicular.
III. The humeral (shoulder).
IV. The cubital (elbow).
V. The radio-ulnar.
VI. The radiocarpal (wrist).
VII. The intercarpal.
VIII. The carpometacarpal.
IX. The intermetacarpal.
X. The metacarpophalangeal.
XI. The digital.

I. THE STERNOCLAVICULAR ARTICULATION (fig. 485)

The sternoclavicular articulation is a double arthrodial joint, the joint-cavity being subdivided by an articular disc. The parts entering into its formation are the sternal end of the clavicle, the lateral part of the superior border of the manubrium sterni, and the cartilage of the first rib. The articular surface of the clavicle is much larger than that of the sternum, and is covered with a layer of cartilage,* which is considerably thicker than that on the sternum. The ligaments of this joint are:

The articular capsule.
Sternoclavicular.
Interclavicular.
Costoclavicular.

The **articular capsule** surrounds the articulation; in front and behind it is of considerable thickness, but above, and especially below, it is thin and partakes more of the character of areolar than of true fibrous tissue.

The **sternoclavicular ligament** is a broad band, covering the anterior surface of the articulation; it is attached above to the upper and front part of the

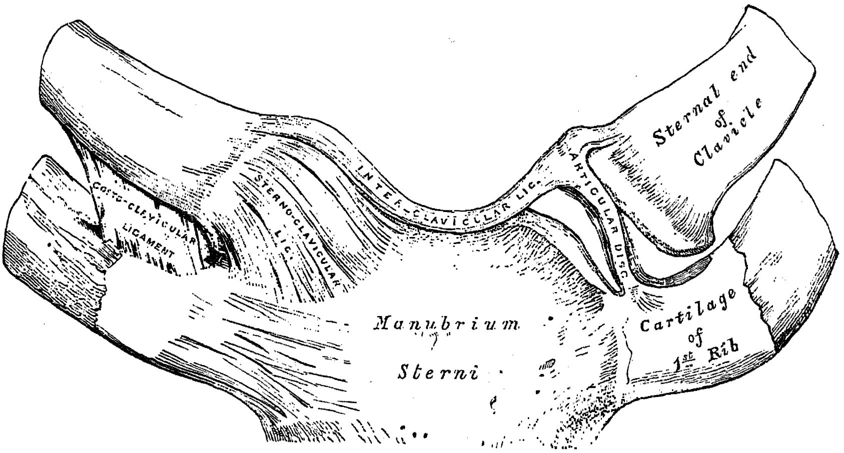
* According to Bruch, the sternal end of the clavicle is covered by a tissue which is fibrous rather than cartilaginous in structure.

sternal end of the clavicle, and, passing obliquely downwards and medialwards, is attached below to the front of the upper part of the manubrium sterni.

The **interclavicular ligament** is continuous above with the fascia colli (deep cervical fascia); it passes from the upper part of the sternal end of one clavicle to that of the other, and is also attached to the upper margin of the manubrium sterni.

The **costoclavicular ligament** (rhomboid ligament) is short, flat, strong, and rhomboid in form. Attached below to the upper surface of the cartilage of the first rib, it ascends backwards and lateralwards, and is fixed above to the costal tuberosity on the under surface of the clavicle.

FIG. 485.—The sternoclavicular articulations. Anterior aspect.



The **articular disc** is flat and nearly circular, and is interposed between the articulating surfaces of the sternum and clavicle. It is attached, above to the upper and posterior border of the articular surface of the clavicle; below to the cartilage of the first rib, near its junction with the sternum; and by the rest of its circumference to the articular capsule. It is thicker at the circumference than at the centre, and divides the joint into two cavities; each of its surfaces is clothed with a synovial stratum.

The *arteries* supplying the joint are derived from the internal mammary and transverse scapular arteries; the *nerves*, from the anterior supraclavicular nerves.

Movements.—This articulation admits of a limited amount of movement in nearly every direction—upwards, downwards, backwards, forwards, as well as circumduction. When these movements take place in the joint, the clavicle in its motion carries the scapula with it, this bone gliding on the outer surface of the chest. This joint therefore forms the centre from which all movements of the supporting arch of the shoulder originate, and is the only point of articulation of the shoulder-girdle with the trunk. The movements attendant on elevation and depression of the shoulder take place between the clavicle and the articular disc. When the shoulder is moved forwards and backwards, the clavicle, with the articular disc, rolls to and fro on the articular surface of the sternum. Elevation of the shoulder is limited principally by the costoclavicular ligament; depression, by the interclavicular ligament and articular disc.

Applied Anatomy.—The strength of this joint depends upon its ligaments, and especially on the articular disc. It is owing to these, and to the fact that the force of the blow is usually transmitted along the long axis of the clavicle, that dislocation rarely occurs, and that the clavicle is broken rather than displaced. Dislocation may be either forwards, backwards or upwards. Should the clavicle be displaced backwards it may cause pressure on the trachea and great vessels of the neck. The chief point worthy of note, as regards the construction of the joint, in connexion with dislocation, is the fact that, owing to the shape of the articular surfaces, and the strength of the joint mainly depending upon the ligaments, the displacement when reduced is very liable to recur.

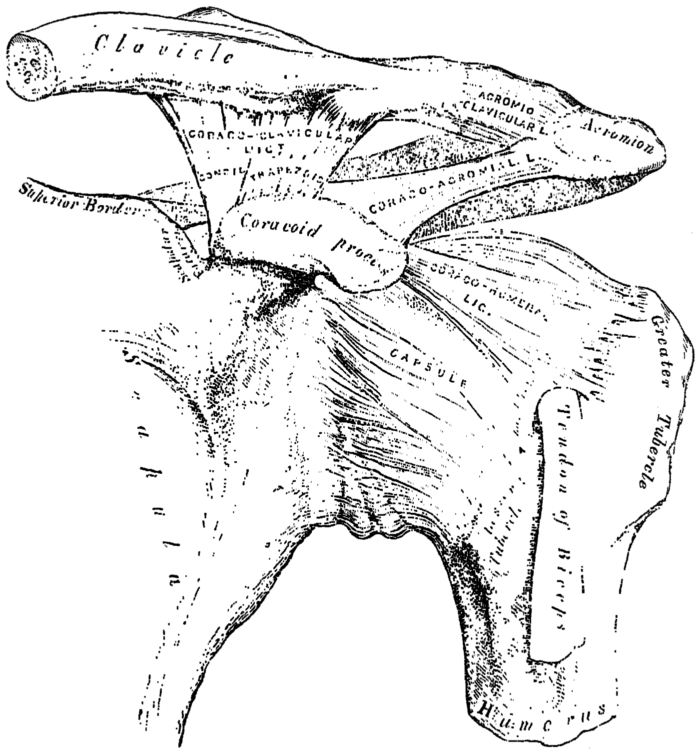
II. THE ACROMIOCLAVICULAR ARTICULATION

The acromioclavicular articulation (fig. 486) is an arthrodial joint between the acromial end of the clavicle and the medial margin of the acromion of the scapula. Its ligaments are :

The articular capsule.	Coracoclavicular { Trapezoid and Conoid.
Acromioclavicular.	

The **articular capsule** completely surrounds the articular margins, and is strengthened above by the acromioclavicular ligament.

Fig. 486.—The ligaments of the left scapula and shoulder-joint. Anterior aspect.



The **acromioclavicular ligament** is a quadrilateral band, covering the superior part of the articulation, and extending between the upper part of the acromial end of the clavicle and the adjoining part of the upper surface of the acromion ; it is composed of parallel fibres, which interlace with the aponeuroses of the Trapezius and Deltoideus.

An articular disc is sometimes found in this joint ; when present, it generally occupies the upper part of the articulation, and only partially separates the articular surfaces. More rarely, it completely divides the joint into two cavities.

The **coracoclavicular ligament** (fig. 486) connects the clavicle with the coracoid process of the scapula. It does not properly belong to the acromioclavicular articulation, but is usually described with it since it forms a most efficient means of retaining the clavicle in contact with the acromion. It consists of two parts, viz. the *trapezoid* and *conoid ligaments*, which are usually separated by a bursa.

The *trapezoid ligament*, the anterior and lateral fasciculus, is broad, thin, and quadrilateral. It is attached, below, to the upper surface of the coracoid process ; above, to the oblique ridge on the under surface of the clavicle.

Its anterior border is free, its posterior is joined with the conoid ligament, the two forming, by their junction, an angle projecting backwards.

The *conoid ligament*, the posterior and medial fasciculus, is a dense band of fibres, conical in form, with its base directed upwards. Its apex is attached to a rough impression at the junction of the ascending and horizontal portions of the coracoid process, medial to the trapezoid ligament; its base is fixed to the coracoid tuberosity on the under surface of the clavicle, and to a line proceeding medialwards from it for 1·25 cm.

The *arteries* supplying the joint are derived from the transverse scapular and thoraco-acromial arteries; the *nerve* is a branch of the suprascapular nerve.

Movements.—The movements of this articulation are of two kinds: (1) a gliding motion of the articular end of the clavicle on the acromion; (2) rotation of the scapula forwards and backwards upon the clavicle. The extent of this rotation is limited by the two portions of the coracoclavicular ligament, the trapezoid limiting rotation forwards, and the conoid backwards.

The acromioclavicular joint has important functions in the movements of the upper extremity. Humphry * pointed out that if there had been no joint between the clavicle and scapula, the circular movement of the scapula on the ribs (as in throwing the shoulders backwards or forwards) would have been attended with a greater alteration in the direction of the shoulder than is consistent with the free use of the arm in such positions, and it would have been impossible to give a blow straight forwards with the full force of the arm: that is to say, with the combined force of the scapula, arm, and forearm. 'This joint,' as he happily says, 'is so adjusted as to enable either bone to turn in a hinge-like manner upon a vertical axis drawn through the other, and it permits the surfaces of the scapula, like the baskets in a roundabout swing, to look the same way in every position, or nearly so.' Again, when the whole arch formed by the clavicle and scapula rises and falls (in elevation or depression of the shoulder), the joint between these two bones enables the scapula still to maintain its lower part in contact with the ribs.

Applied Anatomy.—The acromioclavicular joint owes its security mainly to the coracoclavicular ligament. Owing to the slanting shape of the articular surfaces of this joint, dislocation generally occurs upwards; that is to say, the acromial end of the clavicle is displaced above the acromion of the scapula. The displacement is often incomplete, on account of the strong coracoclavicular ligaments, which remain untorn. The same difficulty exists, as in the sternoclavicular dislocation, in maintaining the end of the bone in position after reduction.

THE LIGAMENTS OF THE SCAPULA

The ligaments of the scapula (fig. 486) are the coraco-acromial, and the superior and inferior transverse.

The **coraco-acromial ligament** is a strong triangular band, extending between the coracoid process and the acromion. Its apex is attached to the edge of the acromion just in front of the articular surface for the clavicle; and its base to the whole length of the lateral border of the coracoid process. This ligament, together with the coracoid process and the acromion, forms an arch for the protection of the head of the humerus. It sometimes consists of two strong marginal bands and a thinner intervening portion, the two bands being attached respectively to the apex and the base of the coracoid process, and joining together at the acromion.

When the Pectoralis minor is inserted, as it is occasionally, into the capsule of the shoulder-joint instead of into the coracoid process, the tendon of the muscle passes between the two bands of the coraco-acromial ligament.

The **superior transverse ligament** (suprascapular ligament) converts the scapular notch into a foramen, and is sometimes ossified. It is a thin and flat fasciculus, narrower at the middle than at the extremities, which are attached to the base of the coracoid process and the medial end of the scapular notch respectively. The suprascapular nerve runs through the foramen; the transverse scapular vessels cross over the ligament.

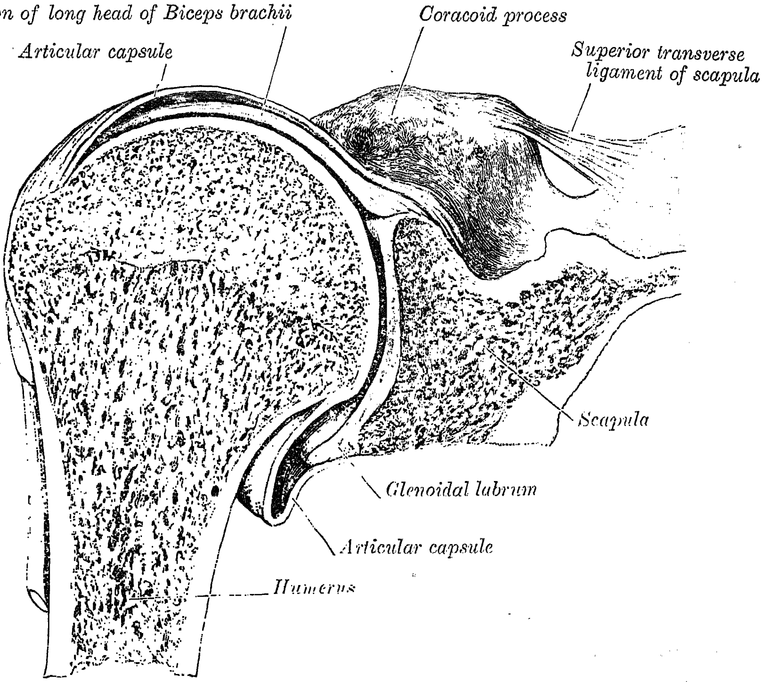
* *A Treatise on the Human Skeleton.*

The **inferior transverse ligament** (spinoglenoid ligament) is a weak membranous band, stretching from the lateral border of the spine of the scapula to the margin of the glenoid cavity. It forms an arch under which the transverse scapular vessels and suprascapular nerve enter the infraspinatous fossa. It is frequently absent.

III. THE HUMERAL ARTICULATION OR SHOULDER-JOINT

The shoulder-joint (figs. 486 to 489) is an enarthrodial or ball-and-socket joint. The bones entering into its formation are the hemispherical head of the humerus and the shallow glenoid cavity of the scapula, a construction which permits of very considerable movement, while the joint itself is protected against

Fig. 487.—A section through the shoulder-joint.



displacement, by the muscles which surround it. The joint is also protected above by an arch, formed by the coracoid process, the acromion, and the coraco-acromial ligament. The articular cartilage on the head of the humerus is thicker at the centre than at the circumference, the reverse being the case with the articular cartilage of the glenoid cavity. The ligaments of the articulation are :

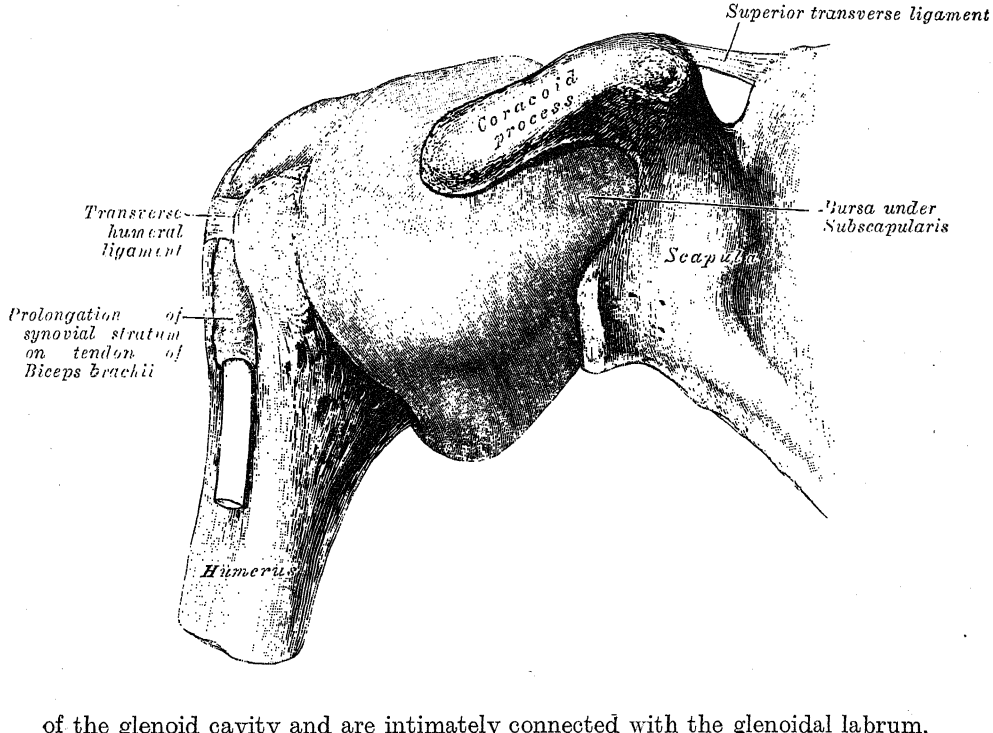
The articular capsule.	The glenoidal labrum.
Coracohumeral.	Transverse humeral.

The **articular capsule** (figs. 486 to 488) envelops the joint, and is attached, above, to the circumference of the glenoid cavity beyond the glenoidal labrum ; below, to the anatomical neck of the humerus, approaching nearer to the articular cartilage at the upper than at the lower part of the neck. It is thicker above and below than elsewhere, and is so remarkably loose and lax, that the bones may be separated from each other for a distance of 2 or 3 cm., an evident provision for the great freedom of movement which is permitted at this articulation. It is strengthened, above, by the Supraspinatus ; below, by the long head of the Triceps brachii ; behind, by the tendons of the Infraspinatus and Teres minor ; and in front, by the tendon of the Subscapularis.

There are usually three openings in the capsule. One anteriorly, below the coracoid process, establishes a communication between the joint and a bursa beneath the tendon of the Subscapularis; another, between the tubercles of the humerus, gives passage to the long tendon of the Biceps brachii; the third, which is not constant, is at the posterior part, between the joint and a bursal sac under the tendon of the Infraspinatus.

Three supplemental bands (fig. 489) which are named the *glenohumeral ligaments*, strengthen the capsule. These are best seen by opening the posterior part of the capsule of the joint and removing the head of the humerus. At their scapular ends they are all attached to the upper part of the medial margin

FIG. 488.—The articular capsule of the right shoulder-joint (distended). Anterior aspect. (From a specimen prepared by J. C. B. Grant.)



of the glenoid cavity and are intimately connected with the glenoidal labrum. The superior band passes along the medial edge of the tendon of Biceps brachii and is attached to a small depression above the lesser tubercle of the humerus; the middle band reaches the lower part of the lesser tubercle; the inferior band extends to the lower part of the anatomical neck of the humerus. In addition to these, the capsule is strengthened in front by two bands, one derived from the tendon of the Pectoralis major, the other from the tendon of the Teres major.

The *synovial stratum* is reflected from the margin of the glenoid cavity over the glenoidal labrum; it is then continued over the inner surface of the capsule, and covers the lower part and sides of the anatomical neck of the humerus as far as the articular cartilage on the head of the bone. The tendon of the long head of the Biceps brachii passes through the fibrous stratum of the capsule and is enclosed in a tubular sheath of the synovial stratum, which is reflected upon it from the summit of the glenoid cavity and is continued round the tendon into the intertubercular sulcus as far as the surgical neck of the humerus (fig. 488).

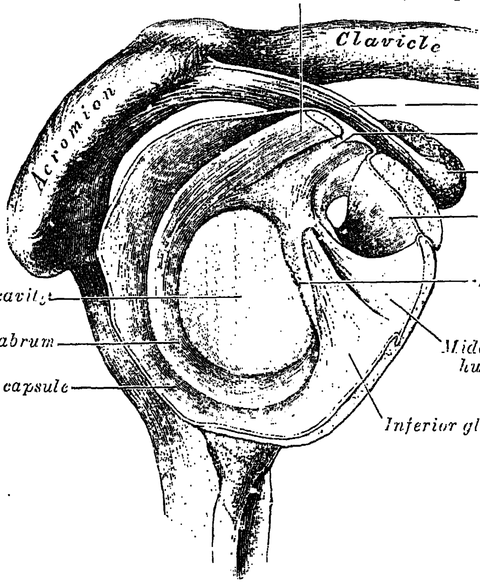
The **coracohumeral ligament** is a broad band which strengthens the upper part of the capsule. It arises from the lateral border of the root of the coracoid process, and passes obliquely downwards and lateralwards to the front of the greater tubercle of the humerus, blending with the tendon of

the Supraspinatus. The hinder and lower border of the ligament is united to the capsule; its anterior and upper border is free, and overlaps the capsule.

The **transverse humeral ligament** (fig. 488) is a broad band passing from the lesser to the greater tubercle of the humerus; it converts the intertubercular sulcus into a canal, and its attachment is always limited to that portion of the bone which lies above the epiphysial line.

The **glenoidal labrum** (glenoid ligament) (fig. 489) is a fibrocartilaginous rim attached round the margin of the glenoid cavity. It is triangular on section, the base being fixed to the circumference of the cavity, while the free edge is thin and sharp. It is continuous above with the tendon of the long head of the Biceps brachii, which gives off two fasciculi to blend with the fibrous tissue of the labrum. It deepens the articular cavity, and protects the edges of the bone. Its attachment to the margin of the glenoid cavity is sometimes deficient in parts; the deficiency occurs most commonly at the notch on the upper part of the medial margin, and a small fringe of the synovial stratum occasionally protrudes through the gap.

FIG. 489.—Interior of shoulder-joint. Lateral aspect.



Bursæ.—The bursæ in the neighbourhood of the shoulder-joint are the following: (1) one is constantly found between the tendon of the Subscapularis and the joint-capsule: it communicates with the synovial cavity through an opening in the front of the capsule; (2) one is sometimes found between the tendon of the Infraspinatus and the capsule; it occasionally opens into the joint; (3) a large one exists between the under surface of the Deltoideus and the capsule, but does not communicate with the joint: this bursa is prolonged under the acromion and coraco-acromial ligament, and intervenes between these structures and the capsule; (4) a large one is situated on the summit of the acromion; (5) one is frequently found between the coracoid process and the capsule; (6) one exists beneath the Coracobrachialis; (7) one lies between the Teres major and the long head of the Triceps brachii; (8) one is placed in front of, and another behind, the tendon of the Latissimus dorsi.

The *muscles* in relation with the joint are, above, the Supraspinatus; below, the long head of the Triceps brachii; in front, the Subscapularis; behind, the Infraspinatus and Teres minor; within, the tendon of the long head of the Biceps brachii. The Deltoideus covers the articulation in front, behind, and laterally.

The *arteries* supplying the joint are derived from the anterior and posterior humeral circumflex, and transverse scapular arteries; the *nerves*, from the axillary (circumflex) and suprascapular nerves.

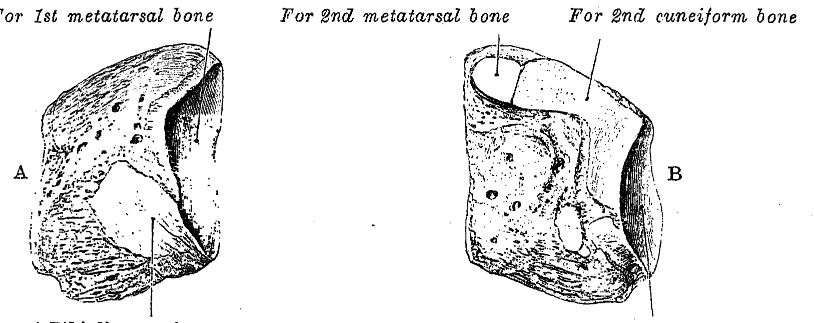
for the attachment of ligaments. The *plantar surface*, irregularly concave, displays on its lateral part a downward projection of varying size, the *plantar process*, to which a portion of the plantar calcaneonavicular ligament is attached. The *medial surface* consists of a rounded *tuberosity*, the lower part of which gives insertion to a large part of the tendon of the Tibialis posterior. Between the tuberosity and the plantar process is a groove for the lodgment of a part of the tendon of the Tibialis posterior. The *lateral surface* is rough and irregular for the attachment of ligaments, and frequently presents a facet for articulation with the cuboid bone.

The Cuneiform Bones (Ossa Cuneiformia)

The **cuneiform bones** (fig. 439), three wedge-shaped bones, articulate with the navicular bone behind and with the first, second, and third metatarsal bones in front; the first cuneiform bone is the largest, and the second the smallest. In the articulated foot the posterior surfaces of the three cuneiform bones form a slight concavity for the navicular, but the anterior portions of the first and third project in front of the anterior surface of the second, and form with it a deep recess in which the base of the second metatarsal bone is lodged.

The **first cuneiform bone** (os cuneiforme primum) (fig. 450) is situated at the medial side of the foot, between the navicular bone behind and the base of the first metatarsal bone in front.

Fig. 450.—The first left cuneiform bone. A. Medial aspect. B. Lateral aspect.



The *medial surface* is subcutaneous, broad and quadrilateral; at its anterior plantar angle is a smooth oval impression, into which a part of the tendon of the Tibialis anterior is inserted. The *lateral surface* is concave; along its superior and posterior borders is a narrow L-shaped articular surface, the vertical limb and posterior part of the horizontal limb of which articulate with the second cuneiform bone, while the anterior part of the horizontal limb articulates with the second metatarsal bone; the facet for the second metatarsal bone is occasionally separated by a groove from that for the second cuneiform bone. The rest of this surface is rough for the attachment of ligaments and part of the tendon of the Peronæus longus. The *anterior surface*, large and kidney-shaped, articulates with the base of the first metatarsal bone. The *posterior surface*, triangular and concave, articulates with the medial facet on the anterior surface of the navicular bone. The *plantar surface* forms the base of the wedge; at its posterior part is a tuberosity for the insertion of part of the tendon of the Tibialis posterior; in front of this a part of the tendon of the Tibialis anterior is inserted. The *dorsal surface* is the thin end of the wedge, and is directed upwards and lateralwards; it is rough for the attachment of ligaments.

The **second cuneiform bone** (os cuneiforme secundum) (fig. 451), of very regular wedge-like form, is situated between the first and third cuneiform bones.

which occur at these articulations. It strengthens the upper part of the articular joint, and prevents the head of the humerus from being pressed up against the acromion when the Deltoideus contracts; it thus fixes the head of the humerus as the centre of motion in the glenoid cavity. By its passage along the intertubercular sulcus it assists in steadying the head of the humerus in the various movements of the arm. When the arm is raised from the side the Biceps brachii assists the Supraspinatus and the Infraspinatus in rotating the head of the humerus in the glenoid cavity. It also holds the head of the bone firmly in contact with the glenoid cavity, and prevents it slipping over the lower edge, and also from being displaced by the action of the Latissimus dorsi and Pectoralis major, as in climbing and many other movements.

Muscles producing the movements.—The muscles moving the shoulder may be divided into: (*a*) those acting on the shoulder-girdle, and (*b*) those acting on the shoulder-joint.

(*a*) **Muscles acting on the shoulder-girdle.**—The chief effect of these muscles is to displace the point of the shoulder, either by pulling directly on the shoulder-girdle or by rotating the scapula. The terms elevation, depression, etc., therefore refer to the point of the shoulder.

Elevation.—Trapezius, Levator scapulæ, Serratus anterior.
Depression.—Pectoralis minor, Rhomboideus major, Subclavius.
Forward movement.—Pectoralis minor, Serratus anterior, Subclavius.
Backward movement.—Trapezius, Levator scapulæ, Rhomboidei.

(*b*) **Muscles acting on the shoulder-joint.**

Flexion.—Subscapularis, Deltoideus (anterior part), Pectoralis major (clavicular head), Coracobrachialis, Biceps brachii.
Extension.—Infraspinatus, Teres minor, Teres major, Latissimus dorsi, Triceps brachii (long head).
Abduction.—Supraspinatus, Deltoideus.
Adduction.—Subscapularis, Infraspinatus, Teres minor, Pectoralis major, Latissimus dorsi, Teres major, Coracobrachialis, Biceps brachii, Triceps brachii.
Rotation inwards.—Subscapularis, Pectoralis major, Latissimus dorsi, Teres major.
Rotation outwards.—Infraspinatus, Teres minor, Deltoideus (posterior fibres).

Applied Anatomy.—Owing to the construction of the shoulder-joint and the freedom of movement which it enjoys, as well as in consequence of its exposed situation, it is more frequently dislocated than any other joint. Dislocation occurs when the arm is abducted, and when, therefore, the head of the humerus presses against the lower and front part of the capsule, which is the thinnest and least supported part of the ligament. The rent in the capsule almost invariably takes place in this situation, and through it the head of the bone escapes, so that the dislocation in most instances is primarily subglenoid. The head of the bone does not usually remain in this situation, between the tendons of the Subscapularis and the Triceps brachii, but generally assumes some other position, which varies according to the direction and amount of force producing the dislocation and the relative strength of the muscles in front of and behind the joint. As the muscles at the back are stronger than those in front, and especially since the long head of the Triceps brachii prevents the bone from passing backwards, dislocation forwards is much the more common. The most frequent position which the head of the humerus ultimately assumes is on the front of the neck of the scapula, beneath the coracoid process, and hence named subcoracoid. Occasionally, in consequence of a greater amount of force being brought to bear on the limb, the head is driven farther medialwards, and rests on the upper part of the front of the chest, beneath the clavicle (subclavicular). Sometimes it remains in the position in which it was primarly displaced, resting on the axillary border of the scapula (subglenoid), and rarely it passes backwards and remains in the infraspinatous fossa, beneath the spine (subspinous). If, after the dislocation has been reduced, abduction of the arm is prevented, the dislocation cannot recur.

Synovitis is attended with effusion into the joint, and when this occurs the capsule is evenly distended, and the contour of the joint rounded. Special projections may occur at the sites of the openings in the capsule. Thus a swelling may appear just medial to the lesser tubercle, from effusion into the bursa beneath the Subscapularis; or, again, a swelling which is sometimes bilobed may be seen in the interval between the Deltoideus and Pectoralis major, from effusion into the diverticulum which runs down the intertubercular groove with the tendon of the Biceps brachii. The effusion into the joint-cavity can be best ascertained by examination from the axilla, where a soft, elastic, fluctuating swelling can usually be felt. In cases of septic synovitis, where incision is

required, the opening should be made in front, over the most prominent point of the swelling. After the pus has been evacuated a counter-opening should be made behind, so as to ensure efficient drainage. In making this counter-opening care should be taken not to injure the axillary nerve, which here lies in contact with the joint-capsule.

The bursa under the Deltoideus may be distended with fluid; this condition may be mistaken for effusion into the joint.

Excision of the shoulder-joint may be required in cases of arthritis (especially the tuberculous form) which have gone on to destruction of the articulation; in compound dislocations and fractures, particularly those arising from gunshot injuries, in which there has been extensive injury to the head of the bone; in some cases of old unreduced dislocation, where there is much pain. The operation is best performed by making an incision from the middle of the coraco-acromial ligament down the arm for about 7 or 8 cm.; this will expose the intertubercular groove containing the tendon of the Biceps brachii, which should be hooked out of the way. The articular capsule is freely opened, and the muscles attached to the greater and lesser tubercles of the humerus are stripped off with the capsule, without dividing their attachments to the latter. The head of the bone can then be thrust out of the wound and sawn off; or divided with a narrow saw *in situ* and subsequently removed. The section should be made, if possible, just below the articular surface, so as to leave the bone as long as possible.

When the shoulder-joint is ankylosed, the loss of movement in the joint is partly compensated for by increased mobility of the scapula. In treating conditions of the shoulder-joint likely to lead to ankylosis the humerus should be kept in the position it assumes when the palm of the hand is placed on the back of the neck, *i.e.* abducted, slightly rotated inwards, and flexed anteriorly, so as to make full use of this compensating mobility of the scapula.

IV. THE CUBITAL ARTICULATION OR ELBOW-JOINT

The elbow-joint includes three articulations :—(1) *humero-ulnar*, between the trochlea of the humerus and the semilunar notch of the ulna, (2) *humero-radial*, between the capitulum of the humerus and the fovea on the head of the radius, and (3) *proximal radio-ulnar*, where the circumference of the radial head is retained in the circle formed by the annular ligament and the radial notch of the ulna (see p. 387). All three are included in a common articular capsule.

The humero-ulnar and humeroradial articulations together form a ginglymus or hinge-joint, the ligaments of which are :

The articular capsule. Ulnar collateral. Radial collateral.

The articular capsule (figs. 492 to 494).—The anterior part of the articular capsule is a broad and thin fibrous layer. It is attached, above, to the front of the medial epicondyle and to the front of the humerus immediately above the coronoid and radial fossæ ; below, to the anterior surface of the coronoid process of the ulna and to the annular ligament (p. 387), being continuous on either side with the collateral ligaments. Its superficial fibres pass obliquely from the medial epicondyle of the humerus to the annular ligament. The middle fibres, vertical in direction, pass from the upper part of the coronoid depression and become partly blended with the preceding, but are inserted mainly into the anterior surface of the coronoid process. The deep or transverse set intersects these at right angles. It is in relation, in front, with the Brachialis, except at its most lateral part.

The posterior part of the articular capsule is thin and membranous, and consists of transverse and oblique fibres. Above, it is attached to the humerus immediately behind the capitulum and close to the medial margin of the trochlea, to the margins of the olecranon fossa, and to the back of the lateral epicondyle some little distance from the trochlea. Below, it is fixed to the upper and lateral margins of the olecranon, to the posterior part of the annular ligament, and to the ulna behind the radial notch. The transverse fibres form a strong fasciculus which bridges the olecranon fossa ; under cover of this band a pouch of the synovial stratum and a pad of fat are displaced into the upper part of the fossa when the joint is extended. In the fat are a few scattered fibrous bundles which pass from the deep surface of the transverse band to the upper part of the fossa. It is in relation, behind, with the tendon of the Triceps brachii and the Anconæus.

The *synovial stratum* (figs. 490, 491) is very extensive. It extends from the margin of the articular surface of the humerus, and lines the coronoid, radial and olecranon fossæ on that bone; it is reflected over the deep surface of the capsule and lines the deep surface of the annular ligament. Projecting into the joint-cavity between the radius and ulna is a crescentic fold of the synovial stratum, suggesting the division of the joint into two: one the humeroradial, the other the humero-ulnar.

Fig. 490.—The articular capsule of the left elbow-joint (distended). Anterior aspect. (From a specimen prepared by J. C. B. Grant.)

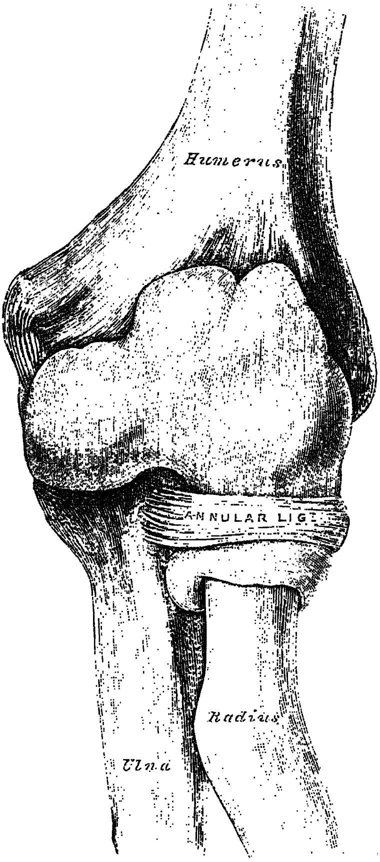
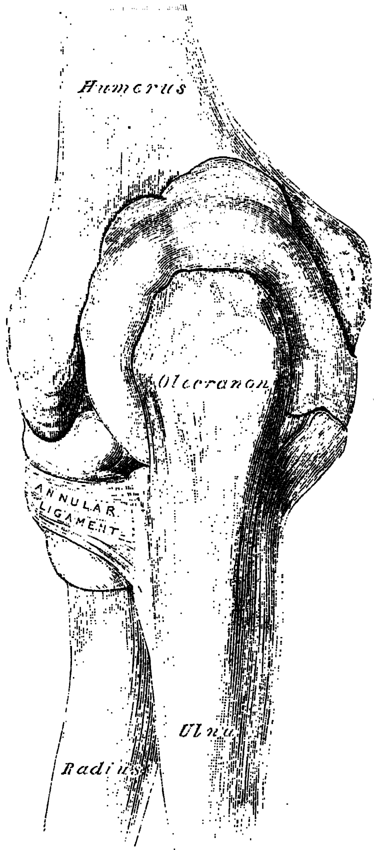


Fig. 491.—The articular capsule of the left elbow-joint (distended). Posterior aspect of the specimen represented in fig. 490.

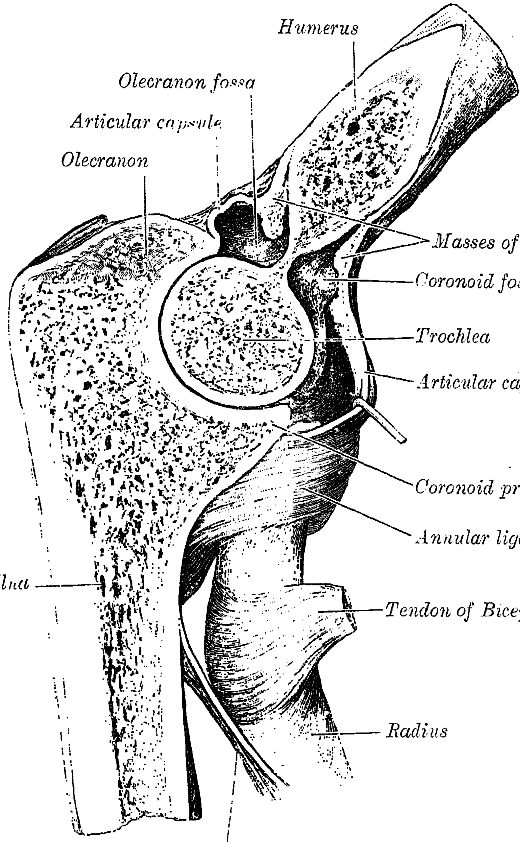


Between the fibrous and the synovial strata of the articular capsule are three masses of fat. The largest, over the olecranon fossa, is pressed into the fossa by the Triceps brachii during flexion; the second, over the coronoid fossa, and the third, over the radial fossa, are pressed by the Brachialis into their respective fossæ during extension.

The **ulnar collateral ligament** (internal lateral ligament) (fig. 493) is a thick triangular band consisting of two portions, an anterior and a posterior, united by a thinner intermediate portion. The *anterior portion*, directed obliquely forwards, is attached, above, by its apex, to the front part of the medial epicondyle of the humerus; and, below, by its broad base, to the medial margin of the coronoid process. The *posterior portion*, also of triangular form, is attached, above, by its apex, to the lower and back part of the medial epicondyle; below, to the medial margin of the olecranon. Between these two bands a few intermediate fibres descend from the medial epicondyle to an *oblique band* which stretches between the olecranon and coronoid processes

and converts the depression on the medial margin of the semilunar notch into a foramen, through which the intra-articular pad of fat is continuous with the extra-articular fat on the medial side of the joint. The ulnar collateral ligament is in relation with the Triceps brachii and Flexor carpi ulnaris and the ulnar nerve, and gives origin to part of the Flexor digitorum sublimis.

FIG. 492.—A sagittal section through the left elbow-joint.



The **radial collateral ligament** (external lateral ligament) (fig. 494), a short and narrow fibrous band, less distinct than the ulnar collateral, is attached, above, to the lower part of the lateral epicondyle of the humerus, and below to the annular ligament, while some of its most posterior fibres pass over that ligament to be inserted into the lateral margin of the ulna. It is intimately blended with the origins of the Supinator and Extensor carpi radialis brevis.

The *muscles* in relation with the joint are, in front, the Brachialis; behind, the Triceps brachii and Anconæus; laterally, the Supinator, and the common tendon of origin of the extensor muscles; medially, the common tendon of origin of the flexor muscles, and the Flexor carpi ulnaris.

The *arteries* supplying the joint are derived from the anastomosis between the profunda and the superior and inferior ulnar collateral branches of the brachial artery, with the anterior, posterior, and interosseous recurrent branches of the ulnar artery, and the recurrent branch of the radial artery. These vessels form an anastomotic network around the joint.

The *nerves* of the joint consist of a twig from the ulnar nerve, as the latter passes between the medial condyle and the olecranon; a filament from the branch of the musculocutaneous nerve to the Brachialis, and two from the median nerve.

The movements at the elbow-joint are described on p. 388.

FIG. 493.—The left elbow-joint. Medial aspect.

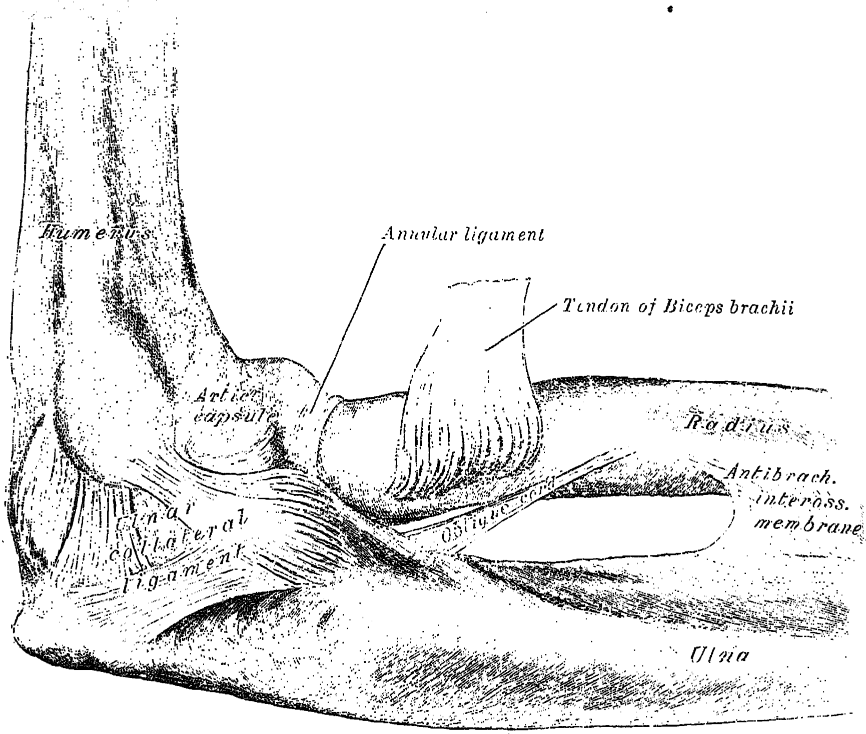
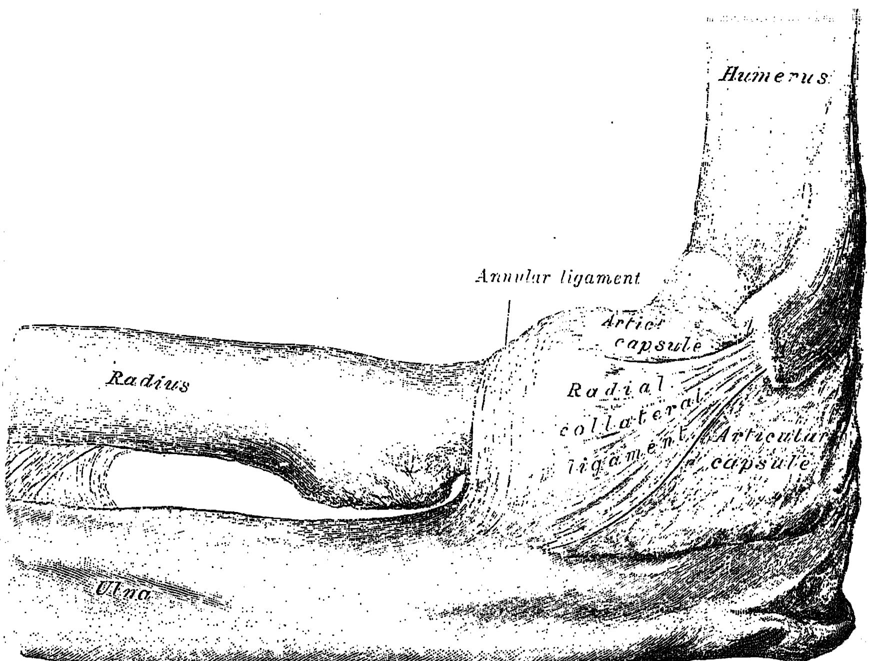


FIG. 494.—The left elbow-joint. Lateral aspect.



V. THE RADIO-ULNAR ARTICULATIONS

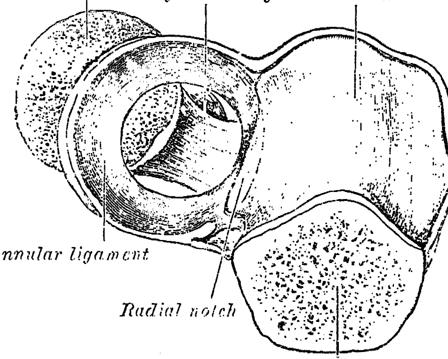
The articulation of the radius with the ulna is effected by ligaments which connect together the extremities and also the bodies of these bones. The ligaments may, consequently, be subdivided into three sets: 1, those of the proximal radio-ulnar articulation; 2, the middle radio-ulnar ligaments; 3, those of the distal radio-ulnar articulation.

1. The Proximal Radio-ulnar Articulation

This articulation forms a trochoid or pivot-joint between the circumference of the head of the radius and the ring formed by the radial notch of the ulna and the annular ligament.

The **annular ligament** (orbicular ligament) (fig. 495) is a strong band of fibres, which encircles the head of the radius, and retains it in contact with the radial notch of the ulna. It forms about four-fifths of the osseofibrous

Fig. 495.—The annular ligament of the left radius. Superior aspect. The head of the radius has been sawn off and the bone dislodged from the ligament.



ring and is attached to the anterior and posterior margins of the radial notch; a few of its lower fibres are continued round below the notch and form at this level a complete fibrous ring. Its upper border blends with the radial collateral ligament and the anterior and posterior parts of the articular capsule of the elbow-joint, while from its lower border a thin loose membrane passes to be attached to the neck of the radius. A thickened band which extends from the inferior border of the annular ligament below the radial notch to the neck of the radius is known as the *quadrate ligament.* The *superficial surface* of the annular ligament is strengthened by the radial collateral ligament of the elbow, and affords origin to part of the Supinator. Its *deep surface* is lined with a synovial stratum which is continuous with that of the elbow-joint.

Movements.—The movements allowed in this articulation are limited to rotatory movements of the head of the radius within the ring formed by the annular ligament and the radial notch of the ulna; rotation forwards being called *pronation*; rotation backwards, *supination.*

2. The Middle Radio-ulnar Union

The bodies of the radius and ulna are connected by the oblique cord and the antibrachial interosseous membrane.

The **oblique cord** (fig. 493) is a small, flattened band, extending from the lateral side of the tubercle of the ulna at the base of the coronoid process to

the radius a little below the radial tuberosity. Its fibres run at right angles to those of the interosseous membrane. It is sometimes wanting.

The **antibrachial interosseous membrane** is a broad and thin sheet, the fibres of which slant obliquely downwards and medialwards from the interosseous crest of the radius to that of the ulna ; the lower part of the membrane is attached to the posterior of the two lines into which the interosseous crest of the radius divides. Two or three bands are occasionally found on the dorsal surface of this membrane ; their fibres descend obliquely from the ulna towards the radius, i.e. at right angles to the other fibres. The membrane is deficient above, commencing about 2 or 3 cm. below the tuberosity of the radius ; is broader in the middle than at either end ; and presents an oval aperture a little above its lower margin, for the passage of the volar interosseous vessels to the back of the forearm. Between its upper border and the oblique cord is a gap, through which the dorsal interosseous vessels pass. The membrane connects the bones, and increases the extent of surface for the attachment of the deep muscles of the forearm. It also transmits to the ulna and thence to the humerus any force acting upwards through the hand and radius. It is relaxed in complete pronation or supination, and is tense when the hand is midway between the prone and supine positions. *In front*, the membrane is in relation, in its upper three-fourths, with the Flexor pollicis longus on the radial side, and with the Flexor digitorum profundus on the ulnar side ; between these muscles are the volar interosseous vessels and nerve ; in its lower one-fourth with the Pronator quadratus ; *behind*, with the Supinator, Abductor pollicis longus, Extensor pollicis brevis, Extensor pollicis longus, Extensor indicis proprius ; and, near the wrist, with the volar interosseous artery and dorsal interosseous nerve.

3. The Distal Radio-ulnar Articulation

This is a pivot-joint formed between the head of the ulna and the ulnar notch of the lower end of the radius ; the surfaces are enclosed in an articular capsule and held together by an articular disc.

The **articular capsule** is slightly thickened in front and behind ; above, it is lax, and with the synovial stratum, projects upwards as a pouch (*recessus sacciformis*) between the radius and the ulna.

The **articular disc** (fig. 498), triangular in shape, binds the lower ends of the ulna and radius firmly together. Its periphery is thicker than its centre, which is occasionally perforated. It is attached by its apex to a depression between the styloid process and the head of the ulna ; and by its base, which is thin, to the prominent edge which separates the ulnar notch from the carpal articular surface of the radius. Its margins are united to the ligaments of the wrist-joint. Its *proximal surface*, smooth and concave, articulates with the head of the ulna. Its *distal surface*, also smooth and concave, forms a part of the radiocarpal joint and articulates with the medial part of the lunate bone ; when the hand is adducted it articulates with the triquetral bone. Each of its surfaces is clothed with a synovial stratum : the proximal, with that of the distal radio-ulnar articulation ; the distal, with that of the radiocarpal joint.

Movements.—The movements of the three joints within the elbow should be studied together. The combination of the movements of flexion and extension of the forearm with those of pronation and supination of the hand, which is ensured by the two being performed at the same joint, is essential to the accuracy of the various minute movements of the hand.

The portion of the joint between the ulna and humerus is a simple hinge-joint, and allows of movements of flexion and extension only, but owing to the obliquity of the trochlea of the humerus, this movement does not take place in the antero-posterior plane of the body of the humerus. When the forearm is extended and supinated, the axes of the arm and forearm are not in the same line ; the arm forms an obtuse angle with the forearm, the hand and forearm being directed lateralwards. During flexion, however, the forearm and the hand tend to approach the middle line of the body, and thus enable the hand to be easily carried to the face. The accurate adaptation of the trochlea of the humerus, with its prominences and depressions, to the semilunar notch of the ulna, prevents any lateral movement.

The joint between the head of the radius and the capitulum of the humerus is an arthrodial joint. The bony surfaces would of themselves constitute an enarthrosis and allow of movement in all directions, were it not for the annular ligament, by which the head of the radius is bound to the radial notch of the ulna, and which prevents any lateral separation of the two bones. It is to the same ligament that the head of the radius owes its security from dislocation, which would otherwise tend to occur, from the shallowness of the cup-like surface on the head of the radius. In fact, but for this ligament, the tendon of the Biceps brachii would be liable to pull the head of the radius out of the joint. The head of the radius is not in complete contact with the capitulum of the humerus in all positions of the joint. The capitulum occupies only the anterior and inferior surfaces of the lower end of the humerus, so that in complete extension a part of the radial head can be plainly felt projecting at the back of the articulation. In full flexion the movement of the radial head is hampered by the compression of the surrounding soft parts, so that the freest rotatory movement of the radius on the humerus (pronation and supination) takes place in semiflexion, in which position the two articular surfaces are in most intimate contact. Flexion and extension of the elbow-joint are limited by the tension of the structures on the front and back of the joint; the limitation of flexion is also aided by the soft structures of the arm and forearm coming into contact.

In any position of flexion or extension, the radius, carrying the hand with it, can be rotated in the proximal radio-ulnar joint. The hand is directly articulated to the lower surface of the radius only, and the ulnar notch on the lower end of the radius travels round the lower end of the ulna. The latter bone is excluded from the wrist-joint by the articular disc. Thus, rotation of the head of the radius round an axis passing through the centre of the capitulum of the humerus imparts circular movement to the hand through a very considerable arc.

The movements in the distal radio-ulnar articulation consist of rotation of the lower end of the radius round an axis which passes through the centre of the head of the ulna. When the radius rotates forwards, *pronation* of the forearm and hand is the result; and when backwards, *supination*. It will thus be seen that in pronation and supination the radius describes the segment of a cone, the axis of which extends from the centre of the head of the radius to the middle of the head of the ulna. In this movement the head of the ulna is not stationary, but describes a curve in a direction opposite to that taken by the head of the radius. This, however, is not to be regarded as a rotation of the ulna—the curve which the head of this bone describes is due to a combined anteroposterior and rotatory movement taking place at the elbow-joint.

Muscles producing the movements.—These muscles may be grouped as (*a*) those acting on the humero-ulnar and humeroradial joints, and (*b*) those acting on the radio-ulnar joints.

(*a*) **Muscles acting on the humero-ulnar and humeroradial joints:**
Flexion.—Brachialis, Brachioradialis, Biceps brachii, Pronator teres.
Extension.—Triceps brachii, Anconæus.

(*b*) **Muscles acting on the radio-ulnar joints:**
Pronation.—Pronator teres, Pronator quadratus.
Supination.—Supinator, Biceps brachii.

Applied Anatomy.—From the breadth of the elbow-joint, and the manner in which the articular surfaces are interlocked, and also on account of the strong collateral ligaments and the support which the joint derives from the mass of muscles attached to the epicondyles of the humerus, lateral displacement of the bones is very uncommon; whereas anteroposterior dislocation, on account of the shortness of the anteroposterior diameter, the weakness of the anterior and posterior parts of the articular capsule, and the want of support of muscles, occurs much more frequently. Dislocation backwards takes place when the forearm is in a position of extension, and forwards when in a position of flexion. For, in the extended position, the coronoid process is not locked into the coronoid fossa, and loses its grip to a certain extent, whereas the olecranon is in the olecranon fossa, and entirely prevents displacement forwards. On the other hand, during flexion, the coronoid process is in the coronoid fossa, and prevents dislocation backwards, while the olecranon, having left the olecranon fossa, is not so efficient in preventing a forward displacement. For the production of lateral dislocation it is necessary that the force should be applied laterally and that either the humerus or the bones of the forearm should be fixed. This is probably the chief reason why this dislocation is so rare; when it does occur it is generally incomplete. Dislocation of the elbow-joint is common in children.

b. Muscles acting *indirectly* on the vertebral column.

Flexion.—Sternocleidomastoideus, Longus capitis and the abdominal muscles.

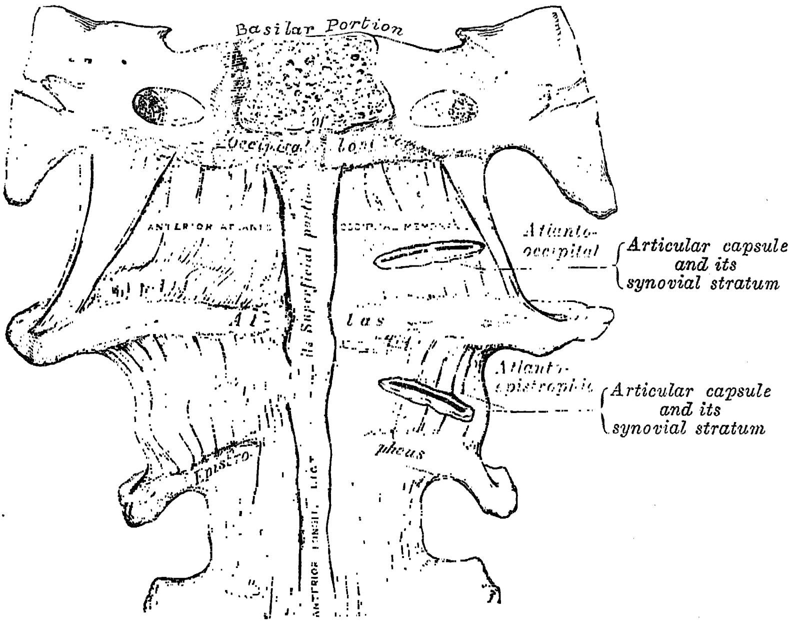
Extension.—Splenius capitis, Semispinalis capitis, Iliocostales lumborum et dorsi, and Longissimi dorsi et capitis.

Lateral flexion and rotation.—Sternocleidomastoideus, Obliqui abdominis, Iliocostales lumborum et dorsi, and Longissimi dorsi et capitis.

4. The Articulation of the Atlas with the Epistropheus

The articulation of the atlas with the epistropheus is of a complicated nature and comprises three joints. There is a pivot-joint between the dens of the epistropheus and the ring formed by the anterior arch and the transverse

Fig. 473.—The anterior atlanto-occipital membrane.



ligament of the atlas (fig. 475), and a pair of arthrodial or gliding joints between the articular surfaces of the two bones. The bones are connected by two articular capsules and by the transverse ligament of the atlas.

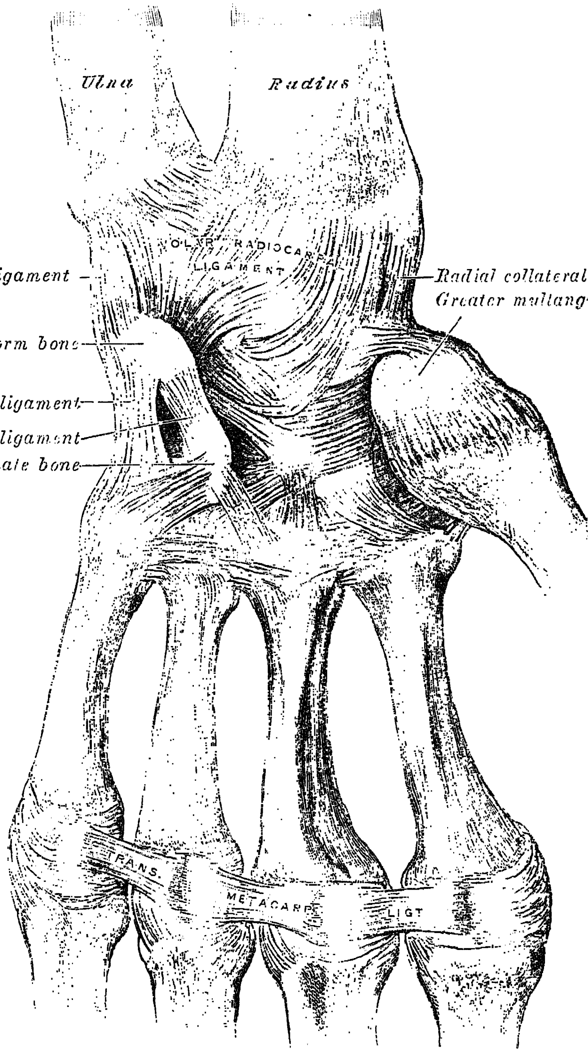
The **articular capsules** are thin and loose, and surround the joints between the articular surfaces. Each is strengthened at its posterior and medial part by an *accessory ligament*, which is attached below to the body of the epistropheus near the base of the dens, and above to the lateral mass of the atlas near the transverse ligament.

In front, the two vertebræ are connected by a continuation of the anterior longitudinal ligament (fig. 473). In this position it is a strong membrane, fixed, above, to the lower border of the anterior arch of the atlas, and below, to the front of the body of the epistropheus. It is strengthened in the middle line by a rounded cord, which connects the tubercle on the anterior arch of the atlas to the body of the epistropheus.

Behind, the atlas and epistropheus are joined by a broad, thin membrane (fig. 473) attached, above, to the lower border of the posterior arch of the atlas, below, to the upper edges of the laminæ of the epistropheus; it is in series with the ligamenta flava.

The **volar radiocarpal ligament** (fig. 496) is a broad membranous band, attached above to the anterior margin of the distal end of the radius, to its styloid process, and to the front of the distal end of the ulna; its fibres pass downwards and medialwards to be attached to the volar surfaces of the navicular, lunate, and triquetral bones, some being continued to the capitate bone.

FIG. 496.—The ligaments of the left wrist and metacarpus. Volar aspect.



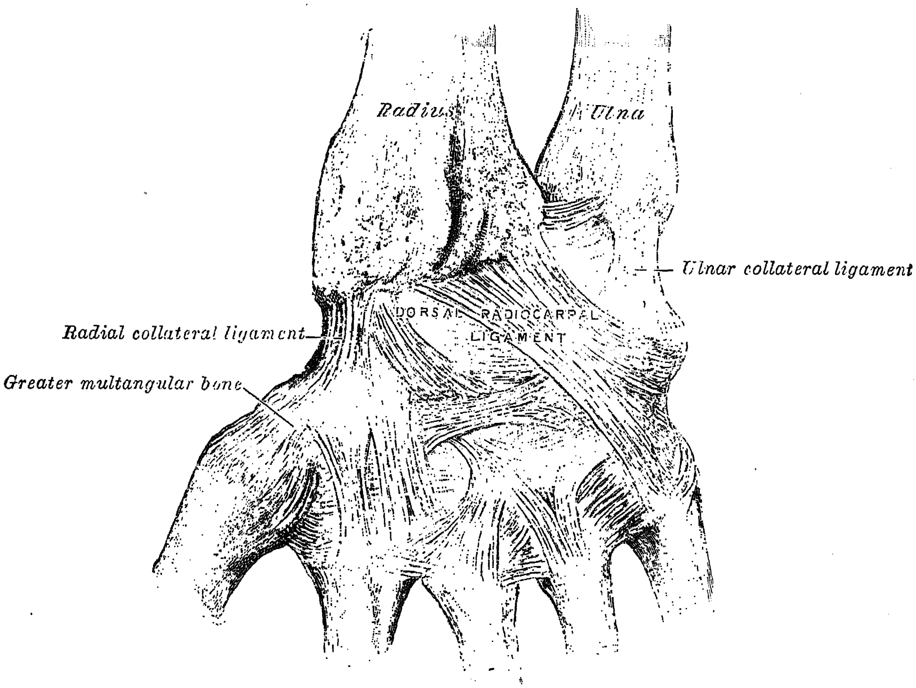
In addition to this broad membrane, there is a rounded fasciculus, superficial to the rest, which reaches from the base of the styloid process of the ulna to the lunate and triquetral bones. The ligament is perforated by apertures for the passage of vessels, and is in relation, in front, with the tendons of the Flexor digitorum profundus and Flexor pollicis longus; behind, it is closely adherent to the anterior border of the articular disc of the distal radio-ulnar articulation.

The **dorsal radiocarpal ligament** (fig. 497), less thick and strong than the volar, is attached, above, to the posterior border of the distal end of the radius; its fibres are directed obliquely downwards and medialwards, and are fixed, below, to the dorsal surfaces of the navicular, lunate, and triquetral bones, being continuous with those of the dorsal intercarpal ligaments. It is in relation, behind, with the extensor tendons of the fingers; in front, it is blended with the articular disc of the distal radio-ulnar articulation.

The **ulnar collateral ligament** (internal lateral ligament) (figs. 496, 497) is attached to the end of the styloid process of the ulna; it divides into two fasciculi, one of which is fixed to the medial side of the triquetral bone, the other to the pisiform bone.

The **radial collateral ligament** (external lateral ligament) (figs. 496, 497) extends from the tip of the styloid process of the radius to the radial side of the navicular bone, some of its fibres being prolonged to the greater multangular bone. It is in relation with the radial artery, which separates the ligament from the tendons of the Abductor pollicis longus and Extensor pollicis brevis.

Fig. 497.—The ligaments of the left wrist. Dorsal aspect.



The *arteries* supplying the joint are the volar interosseous, the volar and dorsal carpal branches of the radial and ulnar, the volar and dorsal metacarpals, and some recurrent branches from the deep volar arch. The *nerves* are derived from the volar and dorsal interosseous nerves.

Movements.—The movements permitted in this joint are flexion, extension, abduction, adduction, and circumduction. Flexion and extension are the most free, and of these a greater amount of extension than of flexion is permitted, since the articulating surfaces extend farther on the dorsal than on the volar surfaces of the carpal bones. In this movement the carpal bones rotate on a transverse axis drawn between the tips of the styloid processes of the radius and ulna. Adduction or ulnar flexion, and abduction or radial flexion are also permitted. The former is considerably greater in extent than the latter on account of the shortness of the styloid process of the ulna, abduction being soon limited by the contact of the styloid process of the radius with the greater multangular bone. In this movement the carpus revolves upon an anteroposterior axis drawn through the centre of the wrist.* Finally, circumduction is permitted by the combined and consecutive movements of adduction, extension, abduction, and flexion. No rotation is possible, but the effect of rotation is obtained by the pronation and supination of the radius on the ulna.

* H. M. Johnston (*Journal of Anatomy and Physiology*, vol. xli.) maintains that in ulnar and radial flexion only slight lateral movement occurs at the radiocarpal joint, and that in complete flexion and extension of the hand there is a small degree of ulnar flexion at the radiocarpal joint.

VII. THE INTERCARPAL ARTICULATIONS

These articulations may be subdivided into three sets: (1) those of the proximal row of carpal bones; (2) those of the distal row of carpal bones; and (3) those of the two rows with each other.

1. The Articulations of the Proximal Row of Carpal Bones

These are arthrodial joints. The navicular, lunate, and triquetral are connected by dorsal, volar, and interosseous ligaments.

The **dorsal and volar ligaments**, two of each, are placed transversely between the bones of the first row; they connect the navicular and lunate bones, and the lunate and triquetral bones. The volar ligaments are weaker than the dorsal.

The **interosseous ligaments** (fig. 498) are two narrow bundles, one connecting the lunate and navicular bones, the other the lunate and triquetral bones. They are on a level with the proximal surfaces of these bones, and form part of the convex articular surface of the radiocarpal joint.

The ligaments of the pisiform bone are: an articular capsule, and the pisohamate and pisometacarpal ligaments.

The **articular capsule** is thin and connects the pisiform to the triquetral. Its synovial stratum is distinct from that of the other carpal joints.

The **pisohamate ligament** connects the pisiform and hamate bones, and the **pisometacarpal ligament** joins the pisiform bone to the base of the fifth metacarpal bone (fig. 496). These two ligaments are, in reality, prolongations of the tendon of the Flexor carpi ulnaris.

2. The Articulations of the Distal Row of Carpal Bones

These also are arthrodial joints; the bones are connected by dorsal, volar, and interosseous ligaments.

The **dorsal and volar ligaments**, each three in number, extend transversely from one bone to another; one connects the greater and lesser multangular bones, a second the lesser multangular and capitate bones, and a third the capitate and hamate bones.

The three **interosseous ligaments** are much thicker than those of the proximal row; one unites the capitate and hamate bones, a second the capitate and lesser multangular bones, and a third the greater and lesser multangular bones. The first is the strongest; the third is sometimes wanting.

3. The Articulations of the Two Rows of Carpal Bones with each other

The joint between the navicular, lunate, and triquetral bones on the one hand, and the second row of carpal bones on the other, is named the *mid-carpal joint*, and is made up of three portions: in the centre the head of the capitate bone and the superior surface of the hamate bone articulate with the deep cup-shaped cavity formed by the navicular and lunate bones, and constitute a sort of ball-and-socket joint; on the radial side the greater and lesser multangular bones articulate with the navicular bone, and on the ulnar side the hamate bone articulates with the triquetral bone, forming gliding joints.

The ligaments are: dorsal, volar, ulnar, and radial collateral.

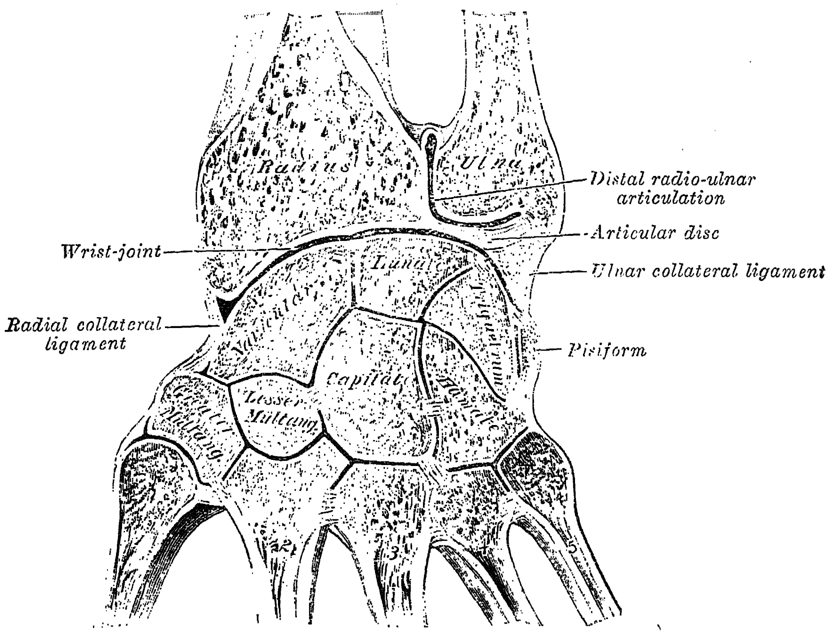
The **dorsal and volar ligaments** consist of short, irregular bundles passing between the bones of the first and second rows. On the volar surface the fibres radiating from the head of the capitate bone to the surrounding bones form the *ligamentum carpi radiatum*.

The **collateral ligaments** are very short: one is placed on the radial, the other on the ulnar side of the carpus: the former, the stronger and more distinct, connects the navicular and greater multangular bones, the latter the

triquetral and hamate bones ; they are continuous with the collateral ligaments of the wrist-joint. In addition to these ligaments, a slender interosseous band sometimes connects the capitate and navicular bones.

The **synovial stratum of the carpus** is very extensive (fig. 498), and bounds a cavity of very irregular shape. The proximal part of the cavity intervenes between the distal surfaces of the navicular, lunate, and triquetral bones and the proximal surfaces of the bones of the second row. It sends two prolongations upwards—between the navicular and lunate bones, and between the lunate and triquetral bones—and three downwards between the four

Fig. 498.—A vertical section through the articulations at the right wrist, showing the synovial cavities.



bones of the second row. The prolongation between the greater and lesser multangular bones, or that between the lesser multangular and capitate bones, is, owing to the absence of the interosseous ligament, often continuous with the cavity of the carpometacarpal joints, sometimes of the second, third, fourth, and fifth metacarpal bones, sometimes of the second and third only. In the latter condition the joint between the hamate bone and the fourth and fifth metacarpal bones has a separate synovial stratum. The synovial cavities of these joints are prolonged for a short distance between the bases of the metacarpal bones. There is a separate synovial stratum between the pisiform and triquetral bones.

Movements.—The chief movements permitted in the mid-carpal joint are flexion and extension, flexion being freer than extension. A very slight amount of rotation is also permitted, the head of the capitate bone rotating round a vertical axis drawn through its own centre.

Muscles producing the movements :

Flexion.—Flexor carpi radialis, Flexor carpi ulnaris, Palmaris longus, Flexores digitorum sublimis et profundus, Flexor pollicis longus.

Extension.—Extensores carpi radiales longus et brevis, Extensor carpi ulnaris, Extensor digitorum communis, Extensores pollicis longus et brevis, Extensor indicis proprius, Extensor digiti quinti proprius.

Adduction.—Flexor carpi ulnaris, Extensor carpi ulnaris.

Abduction.—Abductor pollicis longus, Extensores pollicis longus et brevis, Extensor carpi radialis longus.

Applied Anatomy.—The radiocarpal joint is rarely dislocated, its strength depending mainly upon the numerous strong tendons which surround the articulation. Its security is further provided for by the number of small bones of which the carpus is made up, and which are united by very strong ligaments. The slight movements which take place between the several bones serve to break the jars that result from falls or blows on the hand. Dislocation backwards, which is the more common, simulates to a considerable extent Colles' fracture of the radius, and is liable to be mistaken for it. The differential diagnosis can be easily made by observing the relative positions of the styloid processes of the radius and the ulna. In the natural condition when the arm hangs by the side, the styloid process of the radius is on a lower level, i.e. nearer the ground, than that of the ulna, and this relationship is not disturbed in dislocation. In Colles' fracture, the styloid process of the radius is on the same level as, or even on a higher level than, that of the ulna. A fracture of the lower end of the radius may be caused by a 'back-fire' in starting a motor-car, and is named a chauffeur's fracture; there is usually little displacement and the fracture can only be detected by x-ray examination.

The radiocarpal joint is occasionally the seat of acute synovitis. When the joint cavity is distended with fluid, the swelling is greatest on the dorsal aspect of the wrist, showing a general fulness, with some bulging between the tendons.

The grasp of the hand is strongest when the radiocarpal joint is hyperextended; the wrist, therefore, should be kept in this position during the treatment of any disease or injury likely to lead to ankylosis of the joint.

VIII. THE CARPOMETACARPAL ARTICULATIONS

1. The Carpometacarpal Articulation of the Thumb

This is a joint of reciprocal reception between the first metacarpal and greater multangular bones; it enjoys great freedom of movement on account of the configuration of its articular surfaces, which are saddle-shaped. The joint is surrounded by an **articular capsule** which is thick but loose, and passes from the circumference of the base of the metacarpal bone to the rough edge bounding the articular surface of the greater multangular bone; it is thickest laterally and dorsally. A synovial stratum lines the capsule and is quite distinct from that of the other carpometacarpal joints (fig. 498).

Movements.—In this articulation the movements permitted are flexion, extension, abduction, adduction, circumduction, and opposition. It is by the movement of opposition that the tip of the thumb is brought into contact with the volar surfaces of the slightly flexed fingers. This movement is effected through the medium of a small sloping facet on the anterior lip of the saddle-shaped articular surface of the greater multangular bone. The flexor muscles pull the corresponding part of the articular surface of the metacarpal bone on to this facet, and the movement of opposition is then carried out by the opponens and adductor muscles.

Muscles producing the movements:

Flexion.—Opponens pollicis, Flexores pollicis longus et brevis.
Extension.—Extensores pollicis longus et brevis.
Adduction.—Adductor pollicis, Opponens pollicis, Flexor pollicis brevis.
Abduction.—Abductor pollicis brevis, Extensores pollicis longus et brevis.

2. The Articulations of the Second, Third, Fourth, and Fifth Metacarpal Bones with the Carpus

The joints between the carpus and the second, third, fourth, and fifth metacarpal bones are arthrodial. The bones are united by **articular capsules**, strengthened by dorsal, volar, and interosseous ligaments.

The **dorsal ligaments**, the strongest and most distinct, connect the carpal and metacarpal bones on their dorsal surfaces. The second metacarpal bone receives two fasciculi, one each from the greater and lesser multangular bones; the third metacarpal receives two, one each from the lesser multangular and capitate bones; the fourth two, one each from the capitate and hamate bones; the fifth receives a single fasciculus from the hamate bone, and this is continuous with a similar ligament on the volar surface, forming an incomplete fibrous capsule.

The **volar ligaments** have a somewhat similar arrangement, with the exception of those of the third metacarpal bone, which are three in number: a

lateral one from the greater multangular bone, situated superficially to the sheath of the tendon of the Flexor carpi radialis; an intermediate one from the capitate bone; and a medial one from the hamate bone.

The **interosseous ligaments** consist of short, thick fibres, and are limited to one part of the carpometacarpal articulation; they connect the contiguous inferior margins of the capitate and hamate bones with the adjacent surfaces of the third and fourth metacarpal bones.

The **synovial stratum** of the articular capsules is a continuation of that of the intercarpal joints. Occasionally, the joint between the hamate bone and the fourth and fifth metacarpal bones has a separate synovial stratum.

Movements.—The movements permitted in the carpometacarpal articulations of the fingers are limited to slight gliding of the articular surfaces upon each other, the extent of which varies in the different joints. The metacarpal bone of the little finger is the most movable, then that of the ring-finger; the metacarpal bones of the index and middle fingers are almost immovable.

IX. THE INTERMETACARPAL ARTICULATIONS

The bases of the second, third, fourth, and fifth metacarpal bones articulate with one another by small surfaces covered with cartilage, and are connected together by dorsal, volar, and interosseous ligaments.

The **dorsal and volar ligaments** pass transversely from one bone to another on the dorsal and volar surfaces. The **interosseous ligaments** connect the contiguous surfaces of the bones, just distal to their collateral articular facets.

The **synovial stratum** of these joints is continuous with that of the carpometacarpal articulations.

The **transverse metacarpal ligament** (fig. 496) is a narrow fibrous band, which connects the volar surfaces of the heads of the second, third, fourth, and fifth metacarpal bones. It is blended with the accessory volar ligaments (glenoid ligaments) of the metacarpophalangeal articulations. Its volar surface is grooved where the flexor tendons pass over it; the tendons of the Interossei pass behind the ligament.

X. THE METACARPOPHALANGEAL ARTICULATIONS

These articulations (figs. 499, 500) are of the condyloid kind, formed by the reception of the rounded heads of the metacarpal bones into shallow cavities on the proximal ends of the first phalanges, with the exception of that of the thumb, which presents more of the characteristics of a ginglymoid joint. Each joint has an accessory volar and two collateral ligaments.

The **accessory volar ligaments** (*glenoid ligaments* of Cruveilhier) are thick, dense, fibrocartilaginous structures, placed upon the volar surfaces of the joints in the intervals between the collateral ligaments, to which they are connected; they are loosely united to the metacarpal bones, but are very firmly attached to the bases of the first phalanges. Their volar surfaces are intimately blended with the transverse metacarpal ligament, and grooved for the flexor tendons, the fibrous sheaths of which are connected to the sides of the grooves. Their deep surfaces form parts of the articular facets for the heads of the metacarpal bones.

The **collateral ligaments** are strong, rounded cords, placed on the sides of the joints; each is attached by one extremity to the posterior tubercle and adjacent depression on the side of the head of the metacarpal bone, and by the other to the side of the base of the phalanx.

The dorsal surfaces of these joints are covered with the expansions of the extensor tendons, together with some loose areolar tissue which connects the deep surfaces of the tendons to the bones.*

* Consult an article on 'The nerve supply of the interphalangeal and metacarpophalangeal joints,' by J. S. B. Stopford, *Journal of Anatomy*, vol. lvi. 1921.

Movements.—The movements which occur in these joints are flexion, extension, adduction, abduction, and circumduction; the movements of abduction and adduction are very limited, and cannot be performed when the fingers are flexed.

Fig. 499.—The metacarpophalangeal and digital articulations. Volar aspect.

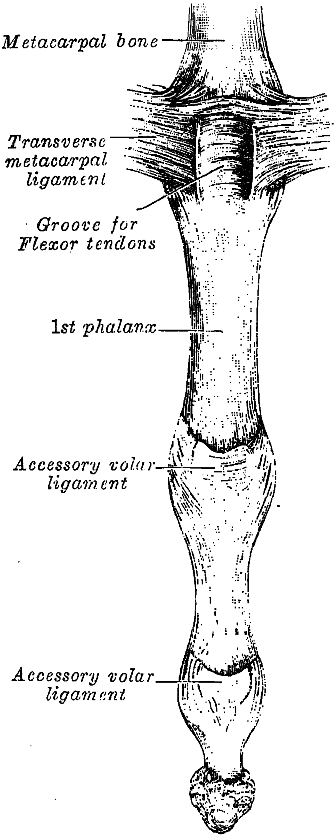
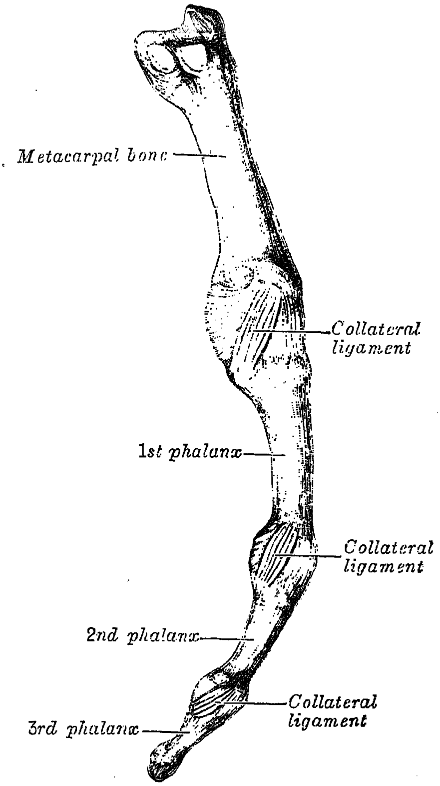


Fig. 500.—The metacarpophalangeal and digital articulations. Medial aspect.



Muscles producing the movements:

Flexion.—Flexores digitorum sublimis et profundus, Lumbricales, Interossei dorsales et volares, Flexores pollicis longus et brevis, Flexor digiti quinti brevis.

Extension.—Extensor digitorum communis, Extensores pollicis longus et brevis, Extensor indicis proprius, Extensor digiti quinti proprius.

Adduction.—Interossei volares, Adductor pollicis, long flexors of fingers and thumb.

Abduction.—Interossei dorsales, Abductor pollicis brevis, Abductor digiti quinti, long extensors of fingers.

XI. THE DIGITAL ARTICULATIONS (figs. 499, 500)

The digital or interphalangeal articulations are hinge-joints; each has a volar and two collateral ligaments. The arrangement of these ligaments is similar to those in the metacarpophalangeal articulations. The extensor tendons supply the places of dorsal ligaments.

Movements.—The only movements permitted in the interphalangeal joints are flexion and extension; these movements are more extensive between the first and second phalanges than between the second and third. The amount of flexion is very considerable, but extension is limited by the accessory volar ligaments.

Muscles producing the movements :

Flexion.—Flexores digitorum sublimis et profundus, Flexor pollicis longus.

Extension.—Lumbricales, Interossei dorsales et volares, Extensores pollicis longus et brevis.

Applied Anatomy.—Division of the extensor tendons opens the interphalangeal joints. These joints would be frequently sprained were it not that the metacarpophalangeal joints are condyloid articulations, allowing of abduction and adduction, and diminishing the effects of force applied to the sides of the fingers.

THE ARTICULATIONS OF THE LOWER EXTREMITY

The articulations of the lower extremity comprise the following :

I. The sacro-iliac.
II. The pubic symphysis.
III. The coxal (hip).
IV. The knee.
V. The tibiofibular.
VI. The talocrural (ankle).
VII. The intertarsal.
VIII. The tarsometatarsal.
IX. The intermetatarsal.
X. The metatarsophalangeal.
XI. The digital.

I. THE SACRO-ILIAC ARTICULATION

The sacro-iliac articulation is a diarthrodial joint, formed between the auricular surfaces of the sacrum and ilium. The articular surface of each bone is covered with a plate of cartilage which is thicker on the sacrum than on the ilium. These plates are in close contact with each other, and are partly united by patches of soft fibrocartilage, and by fine interosseous fibres. The ligaments of the joint are :

Anterior sacro-iliac. Interosseous sacro-iliac.
Long and short posterior sacro-iliac.

The **anterior sacro-iliac ligament** (fig. 501) covers the anterior and inferior surfaces of the joint and consists of numerous thin bands. The superior fibres of the ligament connect the ala of the sacrum to the adjoining part of the iliac fossa ; the inferior fibres are placed below the arcuate line, and unite the lateral parts of the three upper sacral vertebræ to the pre-auricular sulcus and adjacent part of the ilium.

The **interosseous sacro-iliac ligament** is very strong, and forms the chief bond of union between the two bones. It fills the irregular space immediately above and behind the joint-cavity (figs. 504, 505) and is covered by the posterior sacro-iliac ligaments. It consists of bundles of short fibres which connect the iliac and sacral tuberosities.

The **long posterior sacro-iliac ligament** is oblique in direction ; it connects the third transverse tubercle of the sacrum to the posterior superior iliac spine.

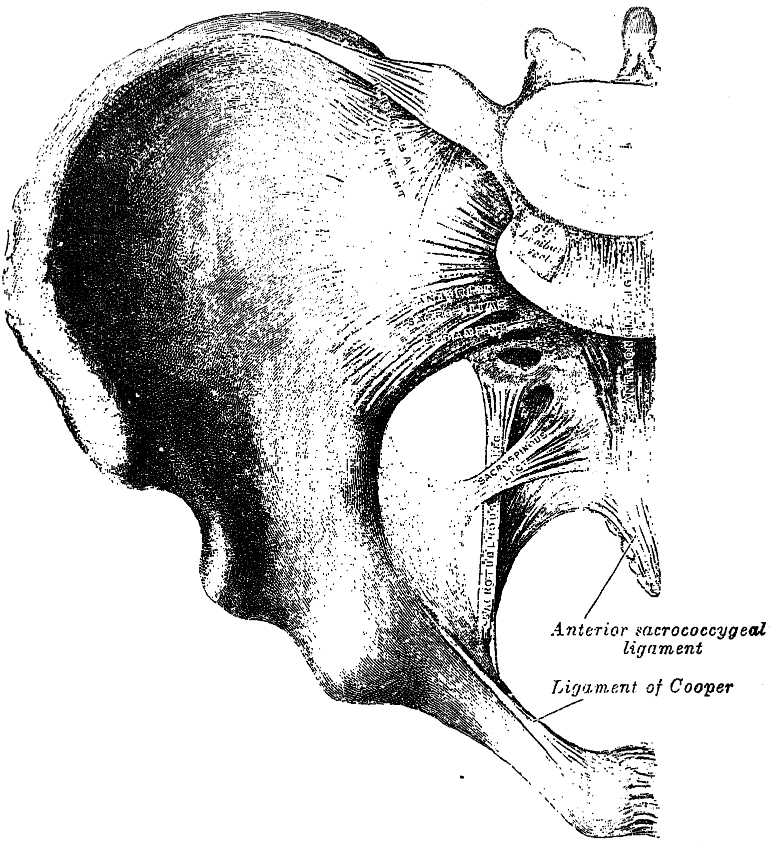
The **short posterior sacro-iliac ligament** (fig. 502) is nearly horizontal in direction, and passes from the posterior superior iliac spine to the first and second transverse tubercles of the sacrum.

The ilium is connected to the fifth lumbar vertebra by the *iliolumbar ligament*, and the sacrum to the ischium by the *sacrotuberous and sacrospinous ligaments*.

The **iliolumbar ligament** (fig. 501) is attached above to the lower and front part of the transverse process of the fifth lumbar vertebra, and occasionally has an additional, weak attachment to the transverse process of the fourth. It radiates as it passes lateralwards and is attached by two main bands to the pelvis. The lower band runs to the ala of the ilium and the base of the sacrum, blending with the anterior sacro-iliac ligament ; the upper is attached to the crest of the ilium immediately in front of the sacro-iliac articulation and is continuous above with the lumbodorsal fascia.

The **sacrotuberous ligament** (great sacrosciatic ligament) (figs. 501, 502) is placed at the lower and posterior part of the pelvis. It is attached by a broad base to the posterior iliac spines, to the third, fourth, and fifth transverse tubercles of the sacrum, and to the lateral margin of the lower part of the sacrum and upper part of the coccyx. Its fibres run obliquely downwards and lateralwards, and converge to form a thick, narrow band; this band widens out below and is fixed to the medial margin of the ischial tuberosity, and is continued along the inferior ramus of the ischium under the name of the *falciform process,* the free concave edge of which gives attachment to the fascia of

FIG. 501.—The articulations of the right side of the pelvis. Anterosuperior aspect.



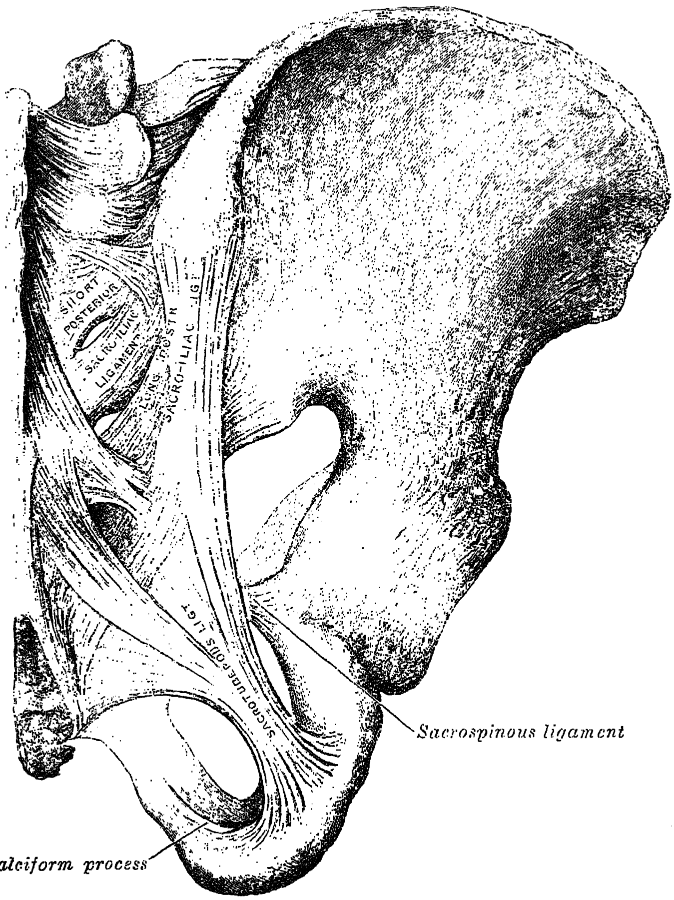
the Obturator internus. Some of the superficial fibres of the lower part of the ligament are continued into the tendon of origin of the long head of the Biceps femoris.

The **sacrospinous ligament** (small sacrosciatic ligament) (fig. 501) is thin, and triangular in form; it is attached by its apex to the spine of the ischium, and, medially, by its broad base, to the lateral margins of the sacrum and coccyx, in front of the sacrotuberous ligament, with which its fibres are intermingled. It is in relation in front with the Coccygeus muscle, to which it is closely connected, and of which it may represent a degenerated part.

These two ligaments convert the sciatic notches into foramina. The *greater sciatic foramen* is bounded, in front and above, by the greater sciatic notch; behind, by the sacrotuberous ligament; and below, by the sacrospinous ligament and the spine of the ischium. It is partially filled up, in the recent state, by the Piriformis muscle which emerges from the pelvis through it. Above this muscle, the superior glutæal vessels and nerve pass out of the pelvis; and below it, the inferior glutæal vessels and nerve, the internal pudendal vessels and nerve, the sciatic and the posterior femoral cutaneous nerves,

and the nerves to the Obturator internus and Quadratus femoris make their exit from the pelvis. The *lesser sciatic foramen* is bounded, in front, by the superior ramus of the ischium; above, by the spine of the ischium and sacrospinous ligament; behind, by the sacrotuberous ligament. It transmits the tendon of the Obturator internus, the nerve to this muscle, and the internal pudendal vessels and nerve.

FIG. 502.—The articulations of the right side of the pelvis. Posterior aspect.



II. THE PUBIC SYMPHYSIS (fig. 503)

The pubic bones are united to one another by a superior and an arcuate pubic ligament, and by an interpubic fibrocartilaginous lamina.

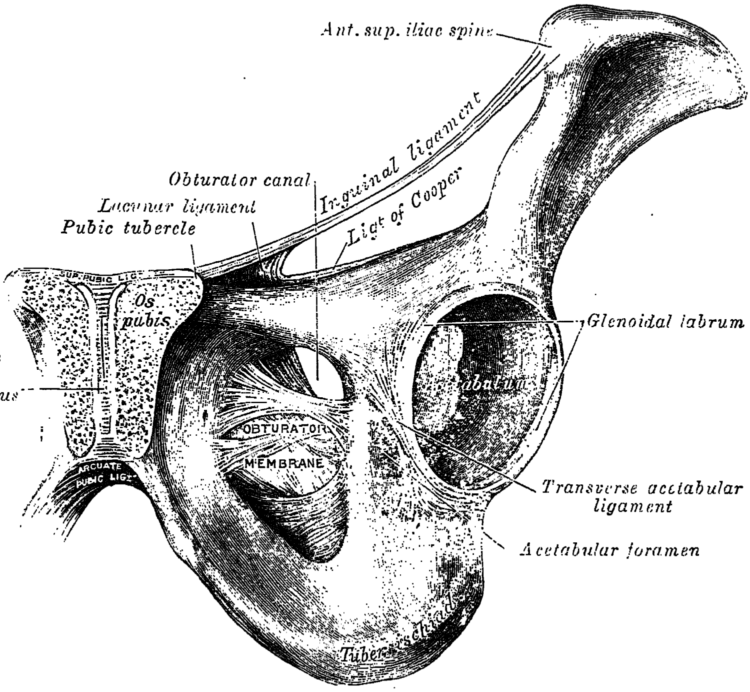
The **superior pubic ligament** connects the pubic bones superiorly, and extends as far as the pubic tubercles.

The **arcuate pubic ligament** (inferior or subpubic ligament) is a thick, triangular arch of fibres, connecting the two pubic bones below, and forming the upper boundary of the pubic arch. Above, it is blended with the interpubic fibrocartilaginous lamina; laterally, it is attached to the inferior rami of the pubic bones; its base is free, and is separated from the fascia of the urogenital diaphragm by an opening through which the deep dorsal vein of the penis (or clitoris) enters the pelvis.

The **interpubic fibrocartilaginous lamina** connects the opposed surfaces of the pubic bones. Each of these surfaces is covered with a thin layer of hyaline cartilage firmly joined to the bone by a series of nipple-like processes which accurately fit into corresponding depressions on the osseous surface. These opposed cartilaginous surfaces are connected by a lamina of fibrocartilage, which varies in thickness in different subjects. It often contains a cavity in its interior, probably formed by the softening and absorption of the fibro-

cartilage, since it rarely appears before the tenth year of life and is not lined with a synovial stratum. This cavity is usually limited to the upper and back part of the joint; it occasionally reaches the front, and may extend the entire length of the cartilage. It may be easily demonstrated when present by

FIG. 503.—A coronal section through the pubic symphysis. Anterior aspect.



making a coronal section of the symphysis pubis near its posterior surface (fig. 503). In front, the lamina is strengthened by several superimposed layers of fibres, which pass obliquely from one bone to the other, decussating and forming an interlacement with the fibres of the aponeuroses of the Obliqui externi and the medial tendons of origin of the Recti abdominis.

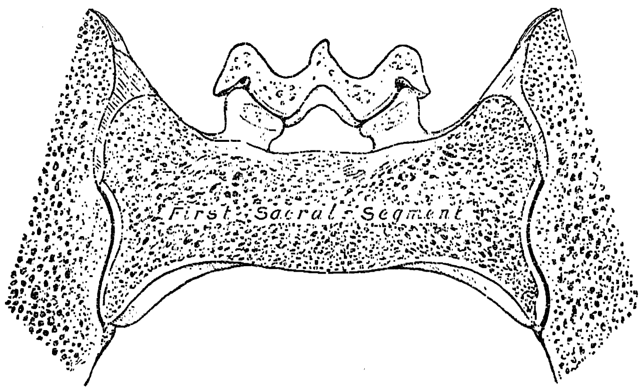
The Mechanism of the Pelvis

The pelvic girdle supports and protects the contained viscera and affords surfaces for the attachments of the muscles of the trunk and lower limb. Its most important mechanical function, however, is to transmit the weight of the trunk and upper limbs to the lower extremities.

It may be divided into two arches by a vertical plane passing through the acetabular cavities; the posterior of these arches is the one chiefly concerned in the function of transmitting the weight of the trunk. Its essential parts are the upper three sacral vertebræ and two strong pillars of bone running from the sacro-iliac articulations to the acetabular cavities. For the reception and diffusion of the weight each acetabular cavity is strengthened by two additional bars running towards the os pubis and the ischium. In order to lessen concussion in rapid changes of distribution of the weight, joints (sacro-iliac articulations) are interposed between the sacrum and the iliac bones; an accessory joint (symphysis pubis) exists in the middle of the anterior arch. The sacrum forms the summit of the posterior arch; the weight transmitted falls on it at the lumbosacral articulation and, theoretically, has a component in each of two directions. One component of the force is expended in driving the sacrum downwards and backwards between the iliac bones, while the other thrusts the upper end of the sacrum downwards and forwards towards the pelvic cavity.

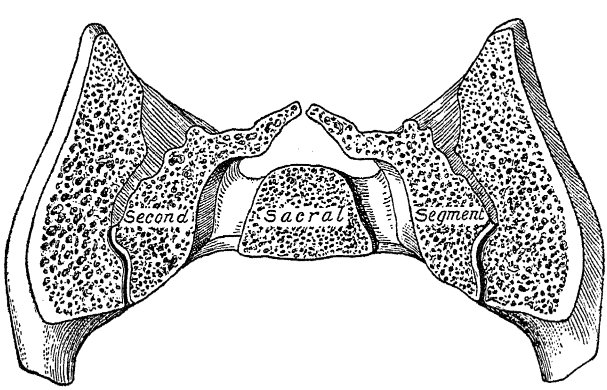
The movements of the sacrum are regulated by its form. Viewed as a whole, it presents the shape of a wedge with its base upwards and forwards. The first component of the force is therefore acting against the resistance of the wedge, and its tendency to separate the iliac bones is resisted by the sacro-iliac and iliolumbar ligaments and by the ligaments of the symphysis pubis.

FIG. 504.—A coronal section through the anterior sacral segment.



If a series of coronal sections be made through the sacro-iliac joints, it will be found possible to divide the articular portion of the sacrum into three segments: anterior, middle, and posterior. In the *anterior segment* (fig. 504), which involves the first sacral vertebra, the articular surfaces show slight sinuosities and are almost parallel to one another. In the *middle segment* (fig. 505) the width between the dorsal margins of the sacral articular surfaces is greater than that between the ventral margins, and in the centre of each surface there is a concavity into which a corresponding convexity of the iliac articular surface fits, forming an interlocking mechanism. In the *posterior segment* (fig. 506) the ventral width of the sacrum is greater than the dorsal, and the articular surfaces are only slightly concave.

FIG. 505.—A coronal section through the middle sacral segment.

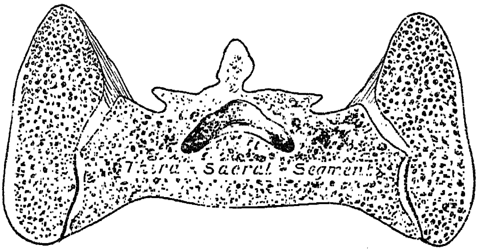


Dislocation downwards and forwards of the sacrum by the second component of the force applied to it is prevented therefore by the middle segment, which interposes the resistance of its wedge-shape and that of the interlocking mechanism on its surfaces; a rotatory movement, however, is produced by which the anterior segment is tilted downwards and the posterior upwards: the axis of this rotation passes through the dorsal part of the middle segment. The movement of the anterior segment is slightly limited by its wedge-form, but chiefly by the posterior and interosseous sacro-iliac ligaments; that of the posterior segment is checked to a slight extent by its wedge-form, but the chief limiting factors are the sacro-tuberous and sacrospinous ligaments. In all these movements the effect of the

sacro-iliac and iliolumbar ligaments and the ligaments of the symphysis pubis in resisting the separation of the iliac bones must be recognised.

During pregnancy the pelvic joints and ligaments are relaxed, and capable therefore of more extensive movements. When the fœtus is being expelled the force is applied to the front of the sacrum. Upward dislocation is prevented by the interlocking mechanism of the middle segment. As the fœtal head passes the anterior segment the latter is carried upwards, enlarging the anteroposterior diameter of the pelvic inlet; when the head reaches the posterior segment this also is pressed upwards against the resistance of its wedge, the movement only being possible by the laxity of the joints and the stretching of the sacrotuberous and sacrospinous ligaments.

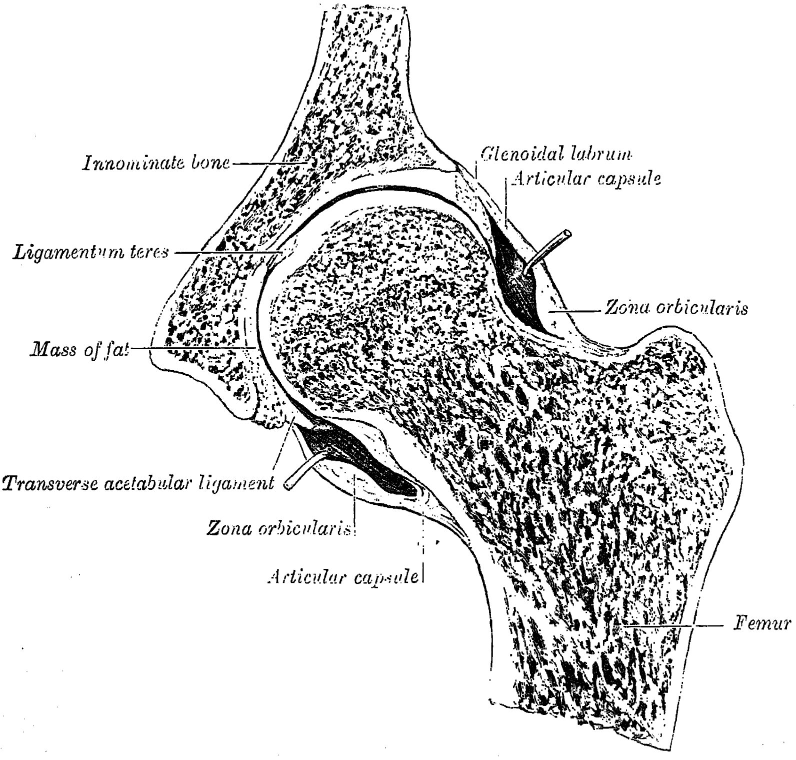
Fig. 506.—A coronal section through the posterior sacral segment.



III. THE COXAL ARTICULATION OR HIP-JOINT

The hip-joint is an enarthrodial or ball-and-socket articulation, formed by the reception of the head of the femur into the cup-shaped cavity of the acetabulum. The articular cartilage on the head of the femur, thicker at the centre than at the circumference, covers the entire surface with the exception of the fovea capitis femoris, to which the ligamentum teres is attached; that

Fig. 507.—A section through the hip-joint.



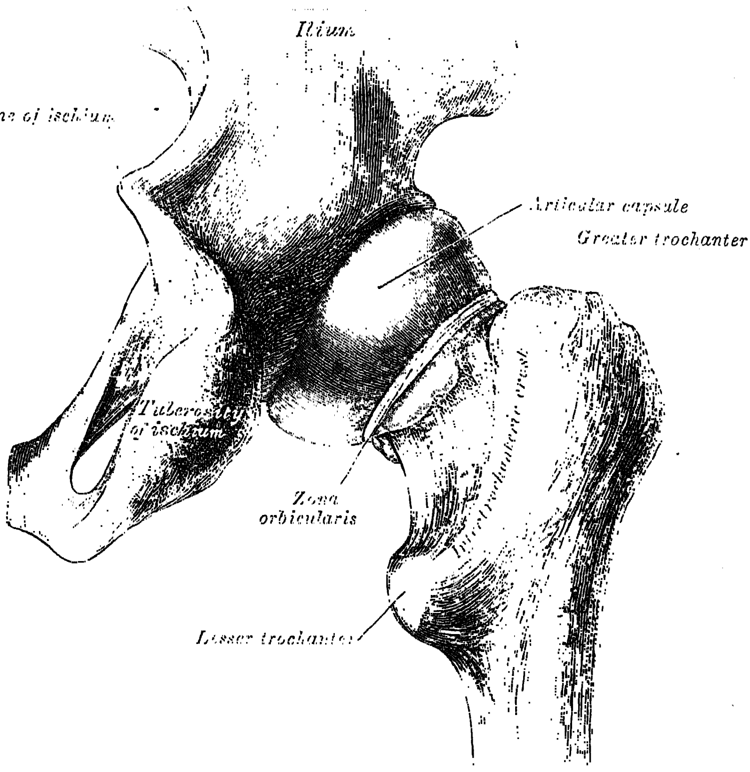
on the acetabulum forms an incomplete ring, the lunate surface. Within the lunate surface there is a circular depression devoid of cartilage, occupied in the recent state by a mass of fat covered with the synovial stratum of the articular capsule. The ligaments of the joint are :

The articular capsule.	Pubocapsular.
Iliofemoral.	Ligamentum teres femoris.
Ischiocapsular.	The glenoidal labrum.

Transverse acetabular.

The **articular capsule** (figs. 507, 508) is strong and dense. Above, it is attached to the margin of the acetabulum, 5 or 6 mm. beyond the glenoidal labrum; in front, it is attached to the outer margin of the labrum, and,

FIG. 508.—The articular capsule of the right hip-joint (distended). Posterior aspect. (From a specimen prepared by J. C. B. Grant.)

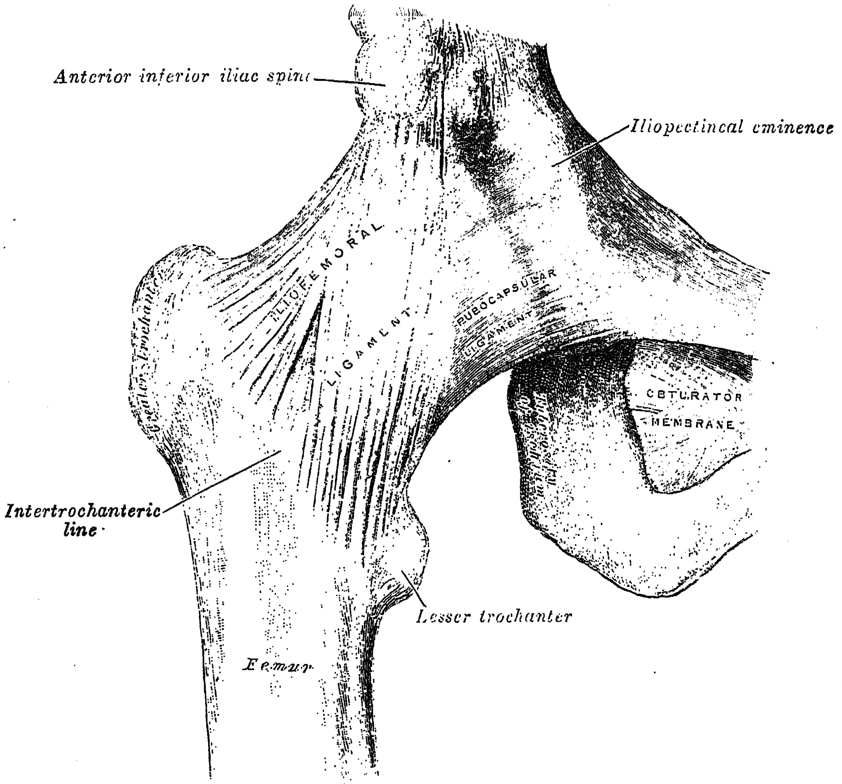


opposite the acetabular notch, to the transverse acetabular ligament and the edge of the obturator foramen. It surrounds the neck of the femur, and is attached, in front, to the intertrochanteric line; above, to the base of the neck; behind, to the neck, about 1 cm. above the intertrochanteric crest; below, to the lower part of the neck close to the lesser trochanter. From its femoral attachment some of the fibres are reflected upwards along the neck as longitudinal bands, termed *retinacula*. The capsule is much thicker at the upper and fore part of the joint, where the greatest amount of resistance is required; behind and below, it is thin and loose. It consists of two sets of fibres, circular and longitudinal. The circular fibres (*zona orbicularis*) are most abundant at the lower and back part of the capsule (figs. 507, 508), and form a sling or collar around the neck of the femur. Anteriorly, they blend with the deep surface of the iliofemoral ligament, and gain an attachment to the anterior inferior iliac spine. The longitudinal fibres are greatest in amount at the upper and front part of the capsule, where they are reinforced by the *iliofemoral ligament*. The articular capsule is also strengthened by the *pubocapsular* and

the *ischiocapsular ligaments.* The external surface of the capsule is rough, covered by numerous muscles, and separated in front from the Psoas major and Iliacus by a bursa which not infrequently communicates through a circular aperture with the cavity of the joint.

The **synovial stratum** is very extensive. Commencing at the margin of the cartilaginous surface of the head of the femur, it covers the portion of the neck which is contained within the joint; from the neck it is reflected on the internal surface of the fibrous stratum of the capsule, covers both surfaces of the glenoidal labrum, ensheathes the ligamentum teres as far as the head

FIG. 509.—The right hip-joint. Anterior aspect.



of the femur, and covers the mass of fat contained in the bottom of the acetabulum. The joint-cavity sometimes communicates, through a hole between the vertical band of the iliofemoral ligament and the pubocapsular ligament, with a bursa situated on the deep surfaces of the Psoas major and Iliacus.

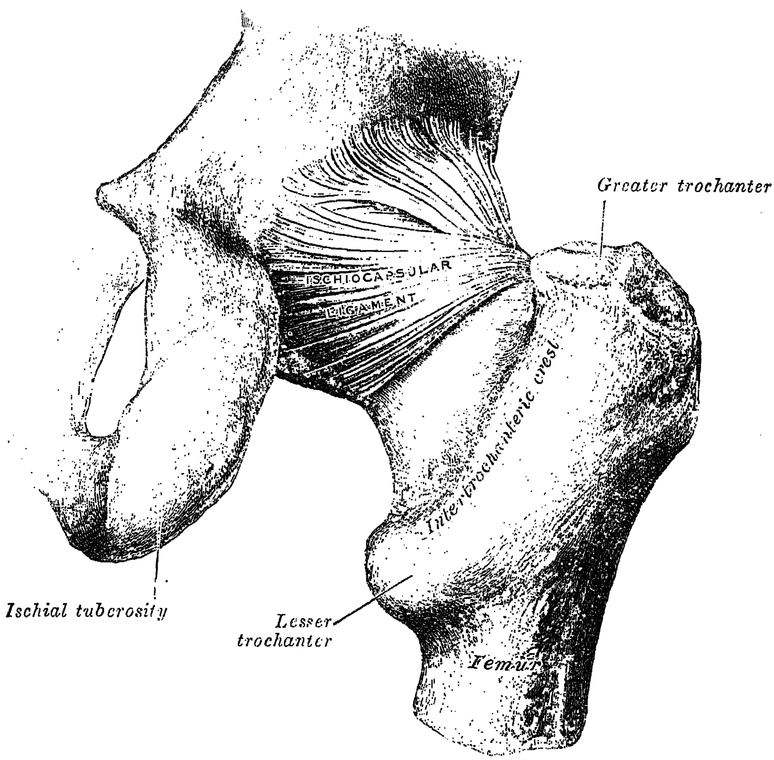
The **iliofemoral ligament** (fig. 509), triangular in shape and of great strength, lies in front of the joint and is intimately connected with the capsule. Its apex is attached to the lower part of the anterior inferior iliac spine, its base to the intertrochanteric line of the femur. The medial and lateral parts of the ligament are strong bands, while the central part is relatively thin and weak; the medial band is vertical in direction and is fixed to the lower part of the intertrochanteric line; the lateral band is oblique and is attached to the upper part of the same line. The iliofemoral ligament is frequently called the Y-shaped ligament of Bigelow, and its lateral band the *iliotrochanteric ligament.*

The **pubocapsular ligament** (fig. 509) is triangular in form with its base at the hip-bone, where it is attached to the iliopectineal eminence, the superior ramus of the os pubis, the obturator crest and obturator membrane; below, it blends with the capsule and with the deep surface of the medial band of the iliofemoral ligament.

The **ischiocapsular ligament** (fig. 510) has a somewhat spiral disposition on the back of the joint. From its attachment to the ischium below and behind the acetabulum, it is directed upwards and lateralwards over the back of the neck of the femur. Some of its fibres are continuous with those of the zona orbicularis, others are fixed to the base of the greater trochanter.

The **ligamentum teres femoris** (fig. 511) is a triangular, somewhat flattened band implanted by its apex on the anterosuperior part of the fovea capitis femoris; its base is attached by two bands, one into either side of the acetabular notch, and between these bony attachments it blends with the transverse ligament. It is ensheathed by the synovial stratum, and varies greatly in strength in different subjects; occasionally only the synovial stratum exists, and in rare cases even this is absent. The ligament is made tense when the thigh is adducted; it is relaxed when the limb is abducted.

FIG. 510.—The right hip-joint. Posterior aspect.



The **glenoidal labrum** (cotyloid ligament) (fig. 503) is a fibrocartilaginous rim attached to the margin of the acetabulum, the cavity of which it deepens; at the same time it protects the edge of the bone, and fills up the inequalities of its surface. It bridges over the acetabular notch as the *transverse acetabular ligament*, and thus forms a complete circle, which closely surrounds the head of the femur and assists in holding it in its place. It is triangular on section, its base being attached to the margin of the acetabulum, while its opposite edge is free and sharp. Its surfaces are invested by the synovial stratum; the internal surface is inclined inwards so as to narrow the acetabulum, and embrace the cartilaginous surface of the head of the femur. It is much thicker above and behind than below and in front.

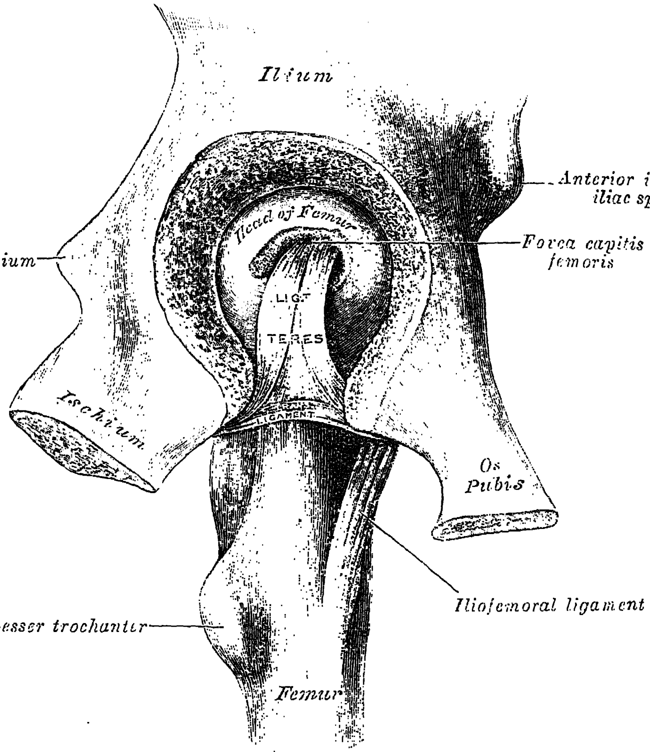
The **transverse acetabular ligament** (fig. 503) is in reality a portion of the glenoidal labrum, though differing from it in having no cartilage-cells among its fibres. It consists of strong, flattened fibres, which cross the acetabular notch, and convert it into a foramen through which the nutrient vessels enter the joint.

The *muscles* in relation with the joint are, in front, the Psoas major and Iliacus,

separated from the capsule by a bursa; above, the reflected head of the Rectus femoris and the insertion of Glutæus minimus, the latter being closely adherent to the capsule; medially, the Obturator externus and Pectineus; behind, the Piriformis, Gemellus superior, tendon of Obturator internus, Gemellus inferior, tendon of Obturator externus, and Quadratus femoris (fig. 512).

The *arteries* supplying the joint are derived from the obturator, medial femoral circumflex, and superior and inferior glutæal arteries.

FIG. 511.—The left hip-joint, opened by removing the floor of the acetabulum from within the pelvis.



The *nerves* are articular branches from the sacral plexus, the sciatic, obturator, and accessory obturator nerves, a branch from the nerve to the quadratus femoris, and a filament from the branch of the femoral nerve supplying the Rectus femoris.

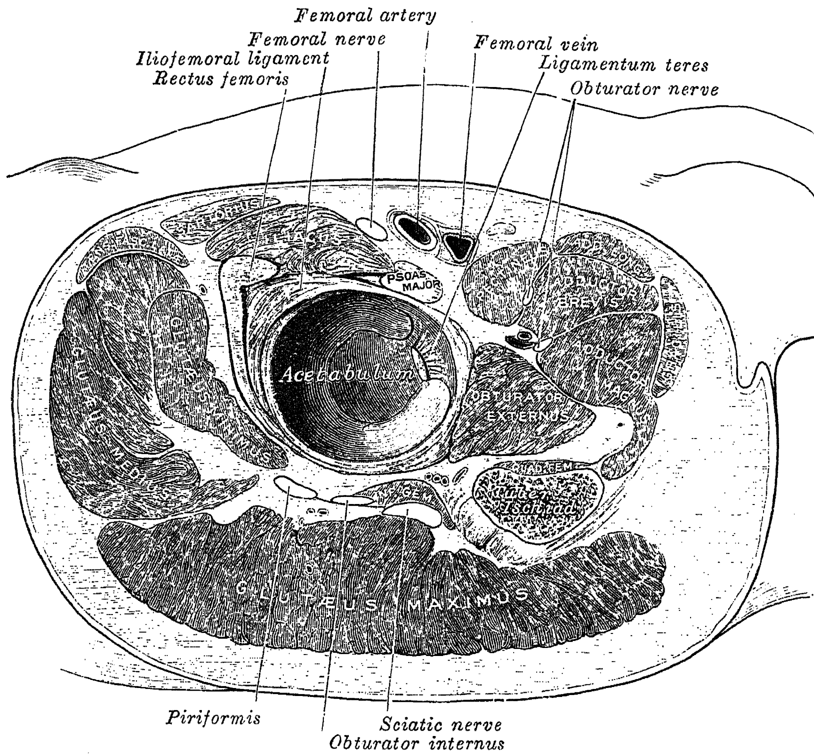
Movements.—The movements of the hip-joint are very extensive, and consist of flexion, extension, adduction, abduction, circumduction, and rotation.

The length of the neck of the femur and its inclination to the body of the bone have the effect of converting the angular movements of flexion, extension, adduction, and abduction partially into rotatory movements in the joint. Thus when the thigh is flexed or extended, the head of the femur, on account of the *medial* inclination of the neck, rotates within the acetabulum. The *forward* slope of the neck similarly affects the movements of adduction and abduction. Conversely rotation of the thigh, which is permitted by the *upward* inclination of the neck, is not a simple rotation of the head of the femur in the acetabulum, but is accompanied by a certain amount of gliding.

The hip-joint presents a very striking contrast to the shoulder-joint in the much more complete mechanical arrangements for its security and for the limitation of its movements. In the shoulder, as has been seen, the head of the humerus is not adapted at all in size to the glenoid cavity, and is hardly restrained in any of its ordinary movements by the capsule. In the hip-joint, on the contrary, the head of the femur is closely fitted to the acetabulum for an area extending over nearly half a sphere, and at the margin of the bony cup it is still more closely embraced by

the glenoidal labrum, so that the head of the femur is held in its place by that ligament even when the fibres of the capsule have been quite divided. The iliofemoral ligament is the strongest of all the ligaments in the body, and is put on the stretch by any attempt to extend the femur beyond a straight line with the trunk. That is to say, this ligament is the chief agent in maintaining the erect position without muscular fatigue; for a vertical line passing through the centre of gravity of the trunk falls behind the centres of rotation in the hip-joints, and therefore the pelvis tends to fall backwards, but is prevented by the tension of the iliofemoral ligaments. The security of the joint may be provided for also by the two bones being directly united through the ligamentum teres, but it is doubtful whether this ligament has much influence upon the mechanism of the joint. When the knee is flexed,

Fig. 512.—The structure surrounding the right hip-joint.



flexion of the hip-joint is arrested by the soft parts of the thigh and abdomen being brought into contact, and when the knee is extended, by the action of the hamstring muscles; extension is checked by the tension of the iliofemoral ligament; adduction by the thighs coming into contact; adduction with flexion by the lateral band of the iliofemoral ligament and the lateral part of the capsule; abduction by the medial band of the iliofemoral ligament and the pubocapsular ligament; rotation outwards by the lateral band of the iliofemoral ligament; and rotation inwards by the ischiocapsular ligament and the hinder part of the capsule.

Muscles producing the movements:

Flexion.—Psoas major, Iliacus, Pectineus, Rectus femoris, Sartorius, Adductores.

Extension.—Glutæus maximus, Biceps femoris, Semitendinosus, Semimembranosus.

Abduction.—Glutæi medius et minimus, Sartorius, Tensor fasciæ latæ.

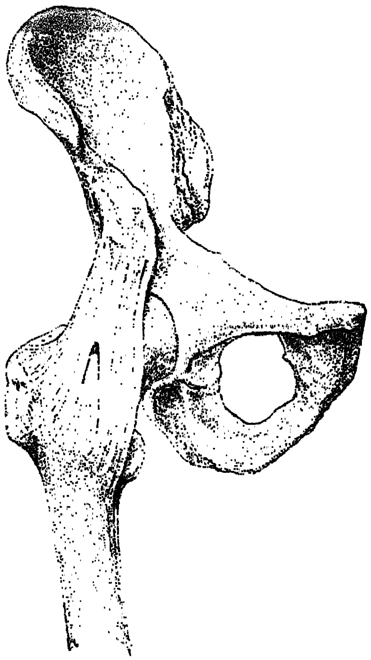
Adduction.—Adductores, Pectineus, Gracilis.

Rotation inwards.—Glutæi medius et minimus (anterior fibres), Tensor fasciæ latæ.

Rotation outwards.—Piriformis, Obturatores, Gemelli, Quadratus femoris Adductores, Sartorius.

Applied Anatomy.—In dislocation of the hip, 'the head of the thigh-bone may rest at any point around its socket' (Bryant); but whatever position it ultimately assumes, the primary displacement is generally downwards and medialwards, the capsule giving way at its weakest—that is, its lower and medial—part. The situation subsequently assumed by the head of the bone is determined by the degree of flexion or extension, and of outward or inward rotation of the thigh at the moment of dislocation, influenced, no doubt, by the iliofemoral ligament, which is not easily ruptured. When, for instance, the head of the bone is forced backwards, this ligament forms a fixed axis, round which the head of the bone rotates, and the latter is driven on to the dorsum of the ilium. The iliofemoral ligament also influences the position of the thigh in the various dislocations; in the dislocations backwards it is tense, and produces inversion of the limb; in the dislocation on to the os pubis, it is relaxed, and therefore allows the external rotator muscles to evert the thigh; while in dislocation into the obturator foramen it is tense, and produces flexion. The muscles inserted into the upper part of the femur, with the exception of the Obturator internus, have very little direct influence in determining the position of the head of the bone. Bigelow, however, has endeavoured to show that the Obturator internus is the principal agent in deciding whether, in the backward dislocations, the head of the bone shall be ultimately lodged on the dorsum of the ilium, or in or near the greater sciatic notch; in both dislocations the head passes, in the first instance, in the same direction. But, as Bigelow asserts, in the displacement on to the dorsum the head of the bone travels up behind the acetabulum, in front of the muscle; while in the dislocation into the greater sciatic notch the head passes behind the muscle, and is prevented from reaching the dorsum, in consequence of the tendon of the muscle arching over the neck of the bone, and it therefore remains in the neighbourhood of the notch. Bigelow distinguishes these two forms of dislocation by describing them as dislocations backwards, 'above and below' the Obturator internus.

Fig. 513.—The right hip-joint, showing the iliofemoral ligament. (After Bigelow.)



The iliofemoral ligament is rarely torn in dislocations of the hip, and this fact is taken advantage of by the surgeon in reducing these dislocations by manipulation. It is made to act as the fulcrum to a lever, of which the long arm is the body of the femur, and the short arm the neck of the bone (fig. 513).

The hip-joint is rarely the seat of acute synovitis from injury, on account of its deep position and its thick covering of soft parts. Acute inflammation may, and does, frequently occur, and in these cases, when the joint is distended with fluid, the swelling is not very easy to detect on account of the thickness of the capsule and the depth of the articulation. It is principally to be found on the front of the joint, just medial to the iliofemoral ligament; or behind, at the lower and back part. In these two places the capsule is thinner than elsewhere.

In chronic hip-disease the affected limb assumes an altered position, the cause of which it is important to understand. In the early stage of a typical case, the limb is flexed, abducted, and rotated outwards. In this position all the ligaments of the joint are relaxed: the front of the capsule by flexion; the lateral band of the iliofemoral ligament by abduction; and the medial band of this ligament and the back of the capsule by rotation outwards. It is, therefore, the position of greatest ease. The condition is not quite obvious at first, upon examining a patient. If the patient be laid in the supine position, the affected limb will be found to be extended and parallel with the other. But it will be seen that the pelvis is tilted downwards on the diseased side and the limb apparently longer than its fellow, and that the lumbar portion of the vertebral column is arched forwards (lordosis). The condition is thus explained: a limb which is flexed and abducted is obviously useless for progression, and in order to overcome the difficulty the patient depresses the affected side of his pelvis, thus producing parallelism of his limbs, and at the same time rotates his pelvis on its transverse horizontal axis, so as to direct the limb downwards, instead of forwards. In the later stages of the disease the limb becomes flexed and adducted and inverted. This position, at all events as regards the adduction, probably results from muscular action and from the patient lying on his

sound side. The adductor muscles are supplied by the obturator nerve, which also largely supplies the joint. These muscles are therefore thrown into reflex spasm by the irritation of the peripheral terminations of this nerve in the inflamed articulation.

Congenital dislocation is more commonly met with in the hip-joint than in any other articulation. The displacement always takes place on to the dorsum ilii. It gives rise to extreme lordosis, in order to throw the weight of the body backwards.

Excision of the hip may be required for disease or for injury, especially gunshot. It may be performed either by an anterior or a posterior incision. The former entails less interference with important structures, especially muscles, than the latter, but permits of less efficient drainage. In the operation from the front an incision is made 8 to 10 cm. in length, starting immediately below and lateral to the anterior superior iliac spine, downwards between the Sartorius and Tensor fasciæ latæ. The interspace between the Glutæus minimus and Rectus femoris is then opened, exposing the upper part of the capsule, which being incised discloses the neck of the bone. The posterior method consists in making an incision 8 to 10 cm. long, commencing midway between the top of the greater trochanter and the iliac crest, and extending down the posterior border of the trochanter. The muscles are detached from the greater trochanter, and the capsule opened freely. When there is a possibility of ankylosis occurring, treatment is carried out with the thigh abducted.

IV. THE KNEE-JOINT

The knee-joint is a ginglymus or hinge-joint. It consists of three articulations in one: two condyloid joints, one between either condyle of the femur and the corresponding meniscus and condyle of the tibia; and a third between the patella and the femur, partly arthrodial, but not completely so, since the articular surfaces are not mutually adapted to each other, so that the movement is not a simple gliding one. This view of the construction of the knee-joint receives confirmation from a study of the articulation in some of the lower mammals, where, corresponding to these three subdivisions, three synovial cavities are sometimes found, either entirely distinct or only connected together by small communications. This view is further rendered probable by the existence in the middle of the joint of the two cruciate ligaments, which may be regarded as the collateral ligaments of the medial and lateral joints. The existence of the patellar fold of synovial membrane would further indicate a tendency to separation of the synovial cavity into two minor sacs, one corresponding to the lateral and the other to the medial joint.

The joint is partly subdivided by two menisci (semilunar fibrocartilages) which are placed between the femur and the tibia.

The ligaments of the joint are:

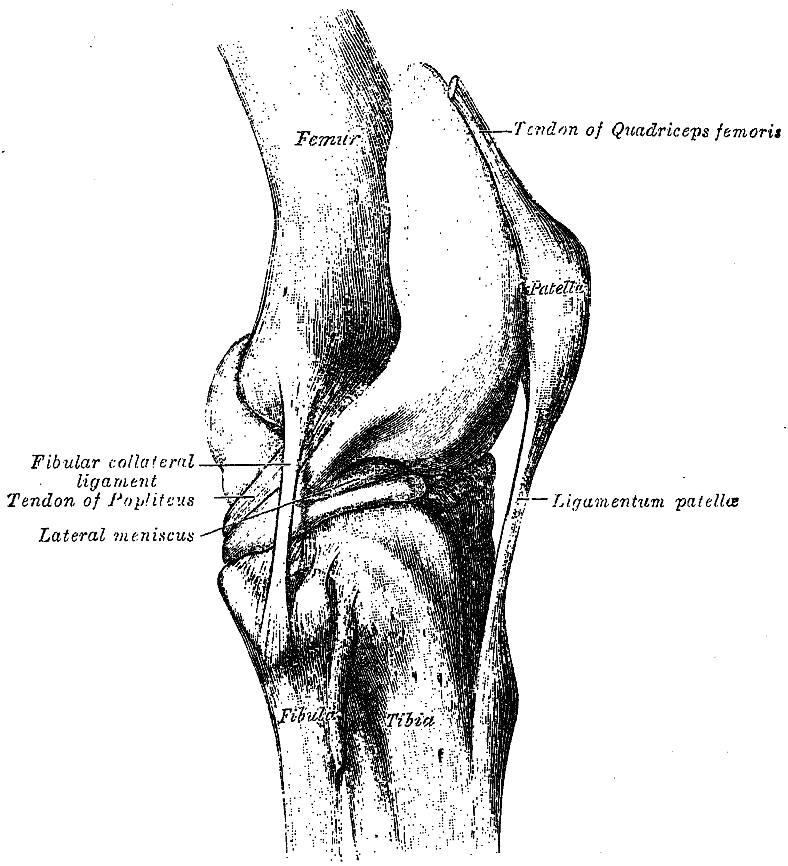
The articular capsule.	Anterior and posterior cruciate.
Ligamentum patellæ.	Transverse.
Oblique and arcuate popliteal.	Coronary.
Tibial and fibular collateral.	

The **articular capsule** (figs. 514, 517) consists of a fibrous stratum which is strengthened in almost its entire extent by bands inseparably connected with it; above and in front, beneath the tendon of the Quadriceps femoris, it is represented only by the synovial stratum. Its chief strengthening bands are derived from the fascia lata and from the tendons surrounding the joint. In front, expansions from the Vasti and from the fascia lata and its iliotibial tract fill the intervals between the collateral and anterior ligaments, constituting the *medial and lateral patellar retinacula*. Behind, the capsule consists of vertical fibres which arise from the condyles of the femur and tibia and from the sides of the inter-condyloid fossa of the femur; the posterior part of the capsule is therefore situated on the sides of the cruciate ligaments and in front of them, and they are thus excluded from the joint-cavity. Behind the cruciate ligaments is the oblique popliteal ligament which is augmented by fibres derived from the tendon of the Semimembranosus. Laterally, a prolongation from the iliotibial tract fills the interval between the oblique popliteal and the fibular collateral ligaments, and partly covers the latter. Medially, expansions from the Sartorius and Semimembranosus pass upwards to the tibial collateral ligament and strengthen the capsule.

The **synovial stratum** of the knee-joint is the largest in the body. Commencing at the upper border of the patella, it forms a large pouch beneath the Quadriceps femoris on the lower part of the front of the femur

(figs. 514, 522), and usually communicates with a bursa interposed between the tendon and the front of the femur. The pouch between the Quadriceps and front of the femur is supported, during the movements of the knee, by a small muscle, the Articularis genus, which is inserted into it. On either side of the patella, the synovial stratum extends beneath the aponeuroses of the Vasti, and more especially beneath that of the Vastus medialis. Below the patella it is separated from the ligamentum patellæ by a considerable quantity of fat, known as the *infrapatellar pad*. From the medial and lateral borders of the articular surface of the patella, reduplications of the synovial

FIG. 514.—The articular capsule of the right knee-joint (distended). Lateral aspect. (From a specimen prepared by J. C. B. Grant.)



stratum project into the interior of the joint. These form two fringe-like folds termed the *alar folds* ; below, these folds converge and are continued as a single band, the *patellar fold* (ligamentum mucosum), to the front of the intercondyloid fossa of the femur (fig. 515). On either side of the joint, the synovial stratum passes downwards from the femur, lining the fibrous stratum of the capsule as far as its attachment to the menisci ; it may then be traced over the upper surfaces of these to their free borders, and thence along their under surfaces to the tibia. At the back part of the lateral meniscus it forms a cul-de-sac between the groove on the surface of the meniscus and the tendon of the Popliteus.

The **ligamentum patellæ** (fig. 517) is the central portion of the common tendon of the Quadriceps femoris, which is continued from the patella to the tuberosity of the tibia. It is a strong, flat, ligamentous band, about 8 cm. in length, attached, above, to the apex and adjoining margins and to the rough depression on the posterior surface of the patella ; and below, to the tuberosity of the tibia ; its superficial fibres are continuous over the front of the patella

Fig. 515.—The right knee-joint. Opened from the front.

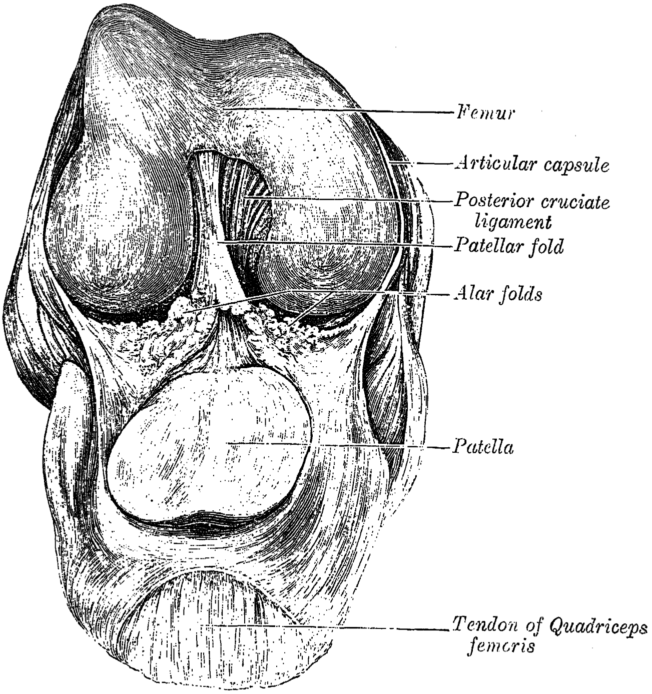
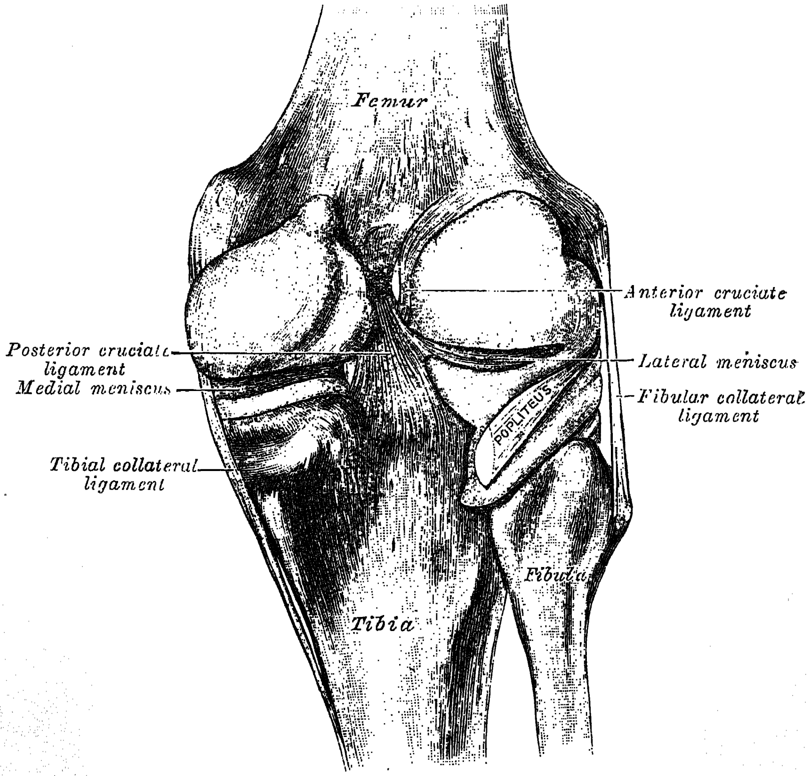


Fig. 516.—The articular capsule of the right knee-joint (distended). Posterior aspect of the specimen represented in fig. 514.

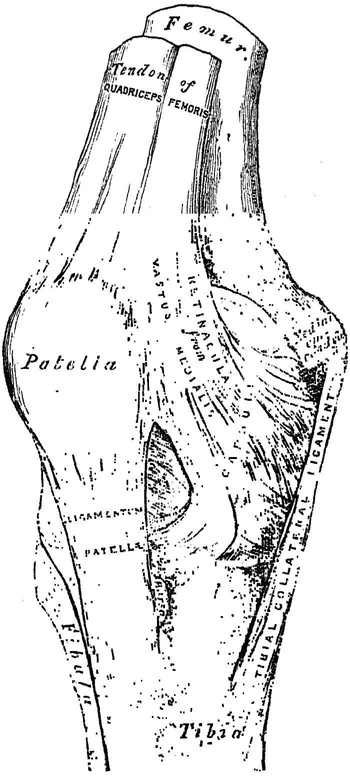


with those of the tendon of the Quadriceps femoris. The medial and lateral portions of the tendon of the Quadriceps pass down on either side of the patella, to be inserted into the upper extremity of the tibia on either side of the tuberosity; these portions merge into the capsule, as stated above, forming the medial and lateral patellar retinacula. The posterior surface of the ligamentum patellæ is separated from the synovial stratum of the articular capsule by a large infrapatellar pad of fat, and from the tibia by a bursa.

The **oblique popliteal ligament** (posterior ligament) (fig. 518) is a broad, flat, fibrous band, formed of fasciculi separated from one another by apertures for the passage of vessels and nerves. It is attached above to the upper margin of the intercondyloid fossa and lateral condyle of the femur, and below it gradually blends with the articular capsule. Superficially there is a strong fasciculus derived from the tendon of the Semimembranosus; it passes from the posterior part of the medial condyle of the tibia obliquely upwards and lateralwards to the posterior part of the lateral condyle of the femur. The oblique popliteal ligament forms part of the floor of the popliteal fossa, and the popliteal artery rests upon it.

The **arcuate popliteal ligament** (fig. 518) is an arched bundle of fibres which varies somewhat in strength and appearance. It is attached to the lateral condyle of the femur and passes downwards to fuse with the capsule below the oblique popliteal ligament. Two bands, an anterior and a posterior, converge from the upper and lower extremities of the arcuate popliteal ligament; they unite below to form the *retinaculum* of the ligament, which is fixed to the apex of the head of the fibula. The anterior band of this retinaculum is sometimes described as the *short fibular collateral ligament*.

Fig. 517.—The right knee-joint. Anteromedial aspect.



The **tibial collateral ligament** (internal lateral ligament) (figs. 517, 518) is a broad, flat band, situated nearer to the back than to the front of the joint. It is attached, above, to the medial epicondyle of the femur immediately below the adductor tubercle; below, to the medial condyle and medial surface of the body of the tibia. The fibres of the posterior part of the ligament are short and incline backwards as they descend; they are inserted into the tibia above the groove for the Semimembranosus. The anterior part of the ligament, about 10 cm. long, inclines forwards as it descends; it is inserted into the medial surface of the body of the tibia about 2 cm. below the level of the condyle. It is crossed, at its lower part, by the tendons of the Sartorius, Gracilis, and Semitendinosus, a bursa being interposed. Its deep surface covers the inferior medial genicular vessels and nerve and the anterior portion of the tendon of the Semimembranosus, with which it is connected by a few fibres; its upper part is intimately adherent to the medial meniscus.

The **fibular collateral ligament** (external lateral ligament) (fig. 520) is a strong, rounded cord, attached, above, to the lateral epicondyle of the femur, immediately above the groove for the tendon of the Popliteus; below, to the lateral side of the head of the fibula, in front of the apex. The greater part of it is hidden by the tendon of the Biceps femoris, but the tendon divides at its insertion into two parts, which are separated by the ligament. Deep to the ligament are the tendon of the Popliteus and the inferior lateral genicular vessels and nerve. The ligament has no attachment to the lateral meniscus.

The **cruciate ligaments** are of considerable strength, and are situated in the middle of the joint, nearer to its posterior than its anterior surface. They are called *cruciate* because they cross each other somewhat like the lines of the letter X; and have received the names *anterior* and *posterior*, from the position of their attachments to the tibia.

The **anterior cruciate ligament** (fig. 519) is attached to the medial part of the anterior intercondyloid fossa of the tibia, being blended with the anterior end of the lateral meniscus; it passes upwards, backwards, and lateralwards, and is fixed into the posterior part of the medial surface of the lateral condyle of the femur.

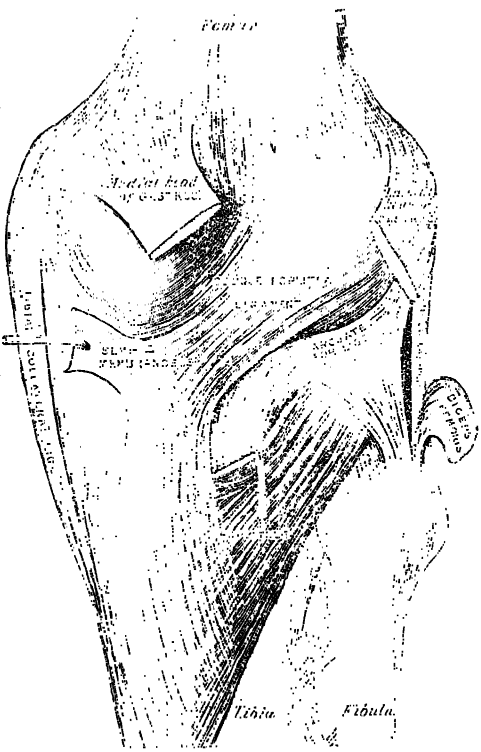


FIG. 518.—The right knee-joint. Posterior aspect.

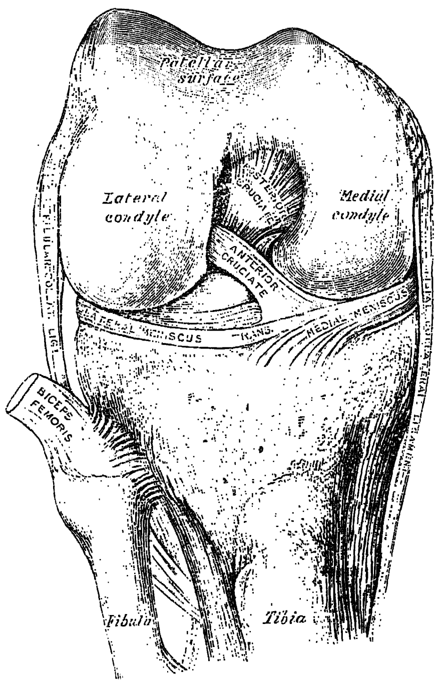


FIG. 519.—The right knee-joint. Dissected from the front.

The **posterior cruciate ligament** (fig. 520) is stronger, but shorter and less oblique in its direction, than the anterior. It is attached to the posterior intercondyloid fossa of the tibia, and to the posterior extremity of the lateral meniscus; it passes upwards, forwards, and medialwards, to be fixed into the anterior part of the lateral surface of the medial condyle of the femur.

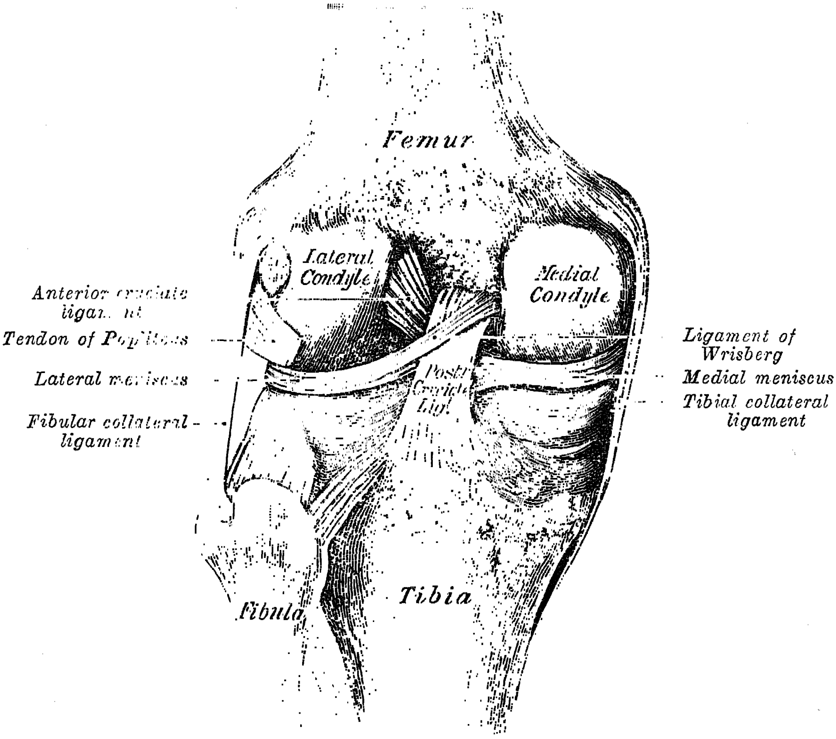
The **menisci** (semilunar fibrocartilages) (fig. 521) are two crescentic lamellæ, which serve to deepen the surfaces of the head of the tibia for articulation with the condyles of the femur. The peripheral border of each meniscus is thick, convex, and attached to the inside of the articular capsule; the opposite border is thin, concave, and free. The upper surfaces of the menisci are concave, and in contact with the condyles of the femur; their lower surfaces are flat, and rest upon the head of the tibia; both surfaces are smooth, and enveloped by the synovial stratum. Each meniscus covers approximately the peripheral two-thirds of the corresponding articular surface of the tibia.

The **medial meniscus** is nearly semicircular in form, a little elongated from before backwards, and broader behind than in front; its anterior end is attached to the anterior intercondyloid fossa of the tibia, in front of the anterior cruciate ligament, some of its fibres being continued, as the transverse ligament, to the

anterior margin of the lateral meniscus ; its posterior end is fixed to the posterior intercondyloid fossa of the tibia, between the attachments of the lateral meniscus and the posterior cruciate ligament.

The **lateral meniscus** is nearly circular and covers a larger portion of the articular surface than the medial meniscus. It is grooved posteriorly for the tendon of the Popliteus, which separates it from the fibular collateral ligament. Its anterior end is attached in front of the intercondyloid eminence of the tibia, behind and lateral to the anterior cruciate ligament, with which it blends ; the posterior end is attached behind the intercondyloid eminence of the tibia, in front of the posterior end of the medial meniscus. The anterior attachment

FIG. 520.—The left knee-joint. Dissected from behind.



of the lateral meniscus is twisted on itself so that its free margin looks backwards and upwards, its anterior end resting on a sloping shelf of bone on the front of the lateral process of the intercondyloid eminence. Close to its posterior attachment it sends off a strong fasciculus, the *ligament of Wrisberg* (figs. 520, 521), which passes upwards and medialwards, to be inserted into the medial condyle of the femur, immediately behind the attachment of the posterior cruciate ligament. Occasionally a small fasciculus passes forwards to be inserted into the lateral part of the anterior cruciate ligament. The lateral meniscus gives off from its anterior convex margin a fasciculus which forms the transverse ligament.

The **transverse ligament** (fig. 521) connects the anterior convex margin of the lateral meniscus to the anterior end of the medial meniscus ; its thickness varies considerably in different subjects, and it is sometimes absent.

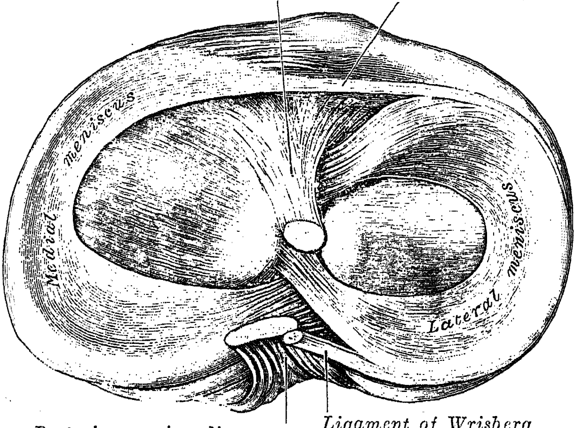
The **coronary ligaments** are merely portions of the capsule, connecting the periphery of either meniscus with the margin of the head of the tibia.

Bursæ.—The bursæ near the knee-joint are the following :

In front there are four bursæ : a large one is interposed between the lower part of the patella and the skin, a small one between the upper part of the tibia and the ligamentum patellæ, a third between the lower part of the tuberosity

of the tibia and the skin, and a fourth between the anterior surface of the lower part of the femur and the deep surface of the Quadriceps femoris, which usually communicates with the knee-joint (fig. 522). Laterally there are four bursæ: (1) one (which sometimes communicates with the joint) between the lateral head of the Gastrocnemius and the capsule; (2) one between the fibular collateral ligament and the tendon of the Biceps femoris; (3) one between the fibular collateral ligament and the tendon of the Popliteus (this is sometimes only an expansion from the next bursa); (4) one between the tendon of the Popliteus and the lateral condyle of the femur, usually an extension from the synovial stratum of the joint. Medially, there are five bursæ: (1) one between the medial head of the Gastrocnemius and the capsule: this sends a prolongation between the tendon of the medial head of the Gastrocnemius and the tendon of the Semimembranosus and often communicates with the joint; (2) one superficial to the tibial collateral ligament, between it and the tendons of the Sartorius, Gracilis, and Semitendinosus; (3) one deep to the tibial collateral ligament, between it and the tendon of the Semimembranosus (this is sometimes

FIG. 521.—The head of right tibia, showing the menisci and the attachments of the cruciate ligaments. Superior aspect.



only an expansion from the next bursa); (4) one between the tendon of the Semimembranosus and the head of the tibia; (5) occasionally there is a bursa between the tendons of the Semimembranosus and Semitendinosus.

Structures around the joint.—In front, and at the sides, is the Quadriceps femoris; laterally, the tendons of the Biceps femoris and Popliteus and the common peronæal nerve; medially, the Sartorius, Gracilis, Semitendinosus, and Semimembranosus; behind, the popliteal vessels, and the tibial nerve, Popliteus, Plantaris, and the medial and lateral heads of Gastrocnemius, some lymph-glands, and fat.

The *arteries* supplying the joint are the highest genicular (anastomotica magna), a branch of the femoral, the genicular branches of the popliteal, the recurrent branches of the anterior tibial, and the descending branch from the lateral femoral circumflex of the arteria profunda femoris.

The *nerves* are derived from the obturator, femoral, tibial, and common peronæal.

Movements.—The movements which take place at the knee-joint are flexion and extension of the leg, and, in certain positions of the joint, internal and external rotation. The movements of flexion and extension at this joint differ from those in a typical hinge-joint, such as the elbow, in that (*a*) the axis round which motion takes place is not a fixed one, but shifts forwards during extension and backwards during flexion; (*b*) the commencement of flexion and the end of extension are accompanied by rotatory movements associated with the fixation of the limb in a position of great stability. In the fully flexed condition the posterior parts of the femoral condyles rest on the corresponding portions of the meniscotibial surfaces, and in this position a slight amount of simple rolling movement is allowed. During

In lesions of this joint it is often difficult to ascertain the exact nature of the injury except by x-ray examination.

The elbow-joint is occasionally the seat of acute synovitis. The joint-cavity then becomes distended with fluid, the bulging showing itself principally around the olecranon, in consequence of the laxness of the articular capsule. Again, there is often some swelling just above the head of the radius, in the line of the radiohumeral joint, or the whole elbow may assume a fusiform appearance. There is not generally much swelling at the front of the joint, though sometimes deep-seated fulness beneath the Brachialis may be noted. When suppuration occurs the abscess usually points at one or other border of the Triceps brachii; occasionally the pus discharges itself in front, near the insertion of the Brachialis. In cases of suppurative synovitis, incisions should be made into the joint on either side of the olecranon, care being taken to avoid wounding the ulnar nerve on the medial side.

The most useful position in which to have the elbow-joint ankylosed is generally at an acute angle, but there are certain occupations, such as those that necessitate wheeling a barrow, when the limb is more useful with the joint ankylosed at an obtuse angle. When both elbow-joints are ankylosed it is important that one should be at an acute angle and the other at an obtuse angle.

Excision of the elbow is principally required for one of three conditions—viz. tuberculous arthritis, injury and its results, and faulty ankylosis—but may be necessary for some other rarer conditions, such as disorganising arthritis after pyæmia and unreduced dislocations. The operation is best performed by a vertical incision down the back of the joint; a straight incision is made about 10 cm. long, the mid-point of which is on a level with and a little to the medial side of the tip of the olecranon. This incision is made down to the bone, through the substance of the Triceps brachii. The operator, guarding the soft parts with his thumb-nail, separates them from the bone with the point of his knife. In doing this there are two structures which he should carefully avoid: the ulnar nerve, which as it courses down between the medial epicondyle and the olecranon lies parallel with, but on the medial side of, the incision; and the prolongation of the Triceps brachii into the deep fascia of the forearm over the Anconæus. After clearing the bones and dividing the collateral and posterior ligaments, the forearm should be strongly flexed and the ends of the bones turned out and sawn off. The turning out of the ends of the bones is rendered easier by first cutting off the olecranon with a pair of cutting bone-forceps. The section of the humerus should be through the base of the epicondyles, that of the ulna and radius should be just below the level of the radial notch of the ulna and the neck of the radius. The synovial stratum which extends on to the neck of the radius must be thoroughly removed when diseased. It is most important to maintain the continuity of the Triceps brachii with the deep fascia of the forearm, so as to obtain good power of extension in the new joint.

Dislocation of the head of the radius alone is a not uncommon accident, and occurs most frequently in young persons from falls on the hand when the forearm is extended and supinated, the head of the bone being displaced forward. It is attended by rupture of the annular ligament. Occasionally a peculiar injury, which is supposed to be a subluxation, occurs in young children. It is believed that the head of the radius is displaced downwards in the annular ligament, the upper border of which becomes folded over the head of the radius, between it and the capitulum of the humerus; the small size of the head of the radius in the child predisposes to this injury. The forearm becomes fixed in a position of semiflexion, midway between supination and pronation, and great pain is complained of upon any attempt to move the joint. The synovial stratum of the proximal radio-ulnar joint is directly continuous with that of the elbow-joint, and, therefore, any septic or tuberculous disease which affects the latter also involves the former joint. The proximal radio-ulnar joint is always removed in an excision of the elbow for disease (see preceding paragraph); for conditions other than disease excision of the lower end of the humerus, without the removal of any part of the radius or ulna.

VI. THE RADIOCARPAL ARTICULATION OR WRIST-JOINT

The radiocarpal articulation or wrist-joint (figs. 496, 497) is a condyloid articulation. The parts forming it are the distal end of the radius and under surface of the articular disc above; and the navicular, lunate, and triquetral bones below. The articular surface of the radius and the distal surface of the articular disc form together a transversely elliptical concave surface, the *receiving cavity*. The proximal articular surfaces of the navicular, lunate, and triquetral bones form a smooth convex surface, the *condyle*, which is received into the concavity. The joint is surrounded by an articular capsule. The *synovial stratum* of the capsule is usually distinct from that of the distal radio-ulnar joint and from that of the carpal joints; the *fibrous stratum* is strengthened by the following ligaments:

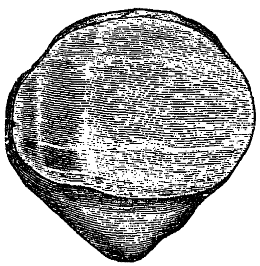
Volar and dorsal radiocarpal. Ulnar and radial collateral.

intercondyloid eminence are received into the fore part of the intercondyloid fossa of the femur. This third phase, by which all these parts are brought into accurate apposition, is known as the 'screwing home,' or locking movement of the joint.

The movement of flexion is the converse of that described above, and is therefore preceded by an external rotation of the femur which unlocks the extended joint.

The axes round which the movements of flexion and extension take place are not precisely at right angles to either bone; when the joint is flexed, the long axes of the femur and tibia are in the same plane, but when extended one bone forms an angle, opening lateralwards, with the other.

FIG. 523.—The posterior surface of the right patella, showing diagrammatically the areas of contact with the femur in different positions of the knee-joint.



In addition to the rotatory movements associated with the completion of extension and the initiation of flexion, rotation inwards or outwards can be effected when the joint is partially flexed; these movements take place mainly between the tibia and the menisci, and are freest when the leg is bent at right angles with the thigh.

Movements of the patella.—The articular surface of the patella is indistinctly divided into seven facets—upper, middle, and lower horizontal pairs, and a medial perpendicular facet (fig. 523). In extreme flexion of the knee-joint the medial perpendicular facet of the patella is in contact with the semilunar surface on the lateral part of the medial condyle of the femur, and the highest of the three lateral facets of the patella with the front part of the lateral condyle. As the leg is carried from the flexed to the extended position, first the highest pair, then the middle pair, and lastly the lowest pair of horizontal facets is successively brought into contact with the patellar surface of the femur. In the extended position, when the Quadriceps femoris is relaxed, the patella lies loosely on the front of the lower end of the femur.

During flexion, the ligamentum patellæ is stretched, and in extreme flexion the posterior cruciate ligament, the oblique popliteal and collateral ligaments and, to a slight extent, the anterior cruciate ligament, are relaxed. Flexion is checked during life by the contact of the leg with the thigh. When the knee-joint is fully extended the oblique popliteal and collateral ligaments, the anterior cruciate ligament, and the posterior cruciate ligament, are rendered tense; in the act of extending the knee, the ligamentum patellæ is tightened by the Quadriceps femoris, but in full extension with the heel supported it is relaxed. Rotation inwards is checked by the anterior cruciate ligament; rotation outwards tends to uncross and relax the cruciate ligaments, but is checked by the tibial collateral ligament. The main function of the cruciate ligaments is to act as a direct bond between the tibia and femur and to prevent the former bone from being carried too far backwards or forwards. They also assist the collateral ligaments in resisting any bending of the joint to either side. The menisci adapt the surfaces of the tibia to the shape of the femoral condyles to a certain extent, and so fill up the intervals which would otherwise be left in the varying positions of the joint, and permit of the two varieties of motion, flexion (and extension), and rotation, as explained above. The patella is a great defence to the front of the knee-joint, and distributes upon a large and tolerably even surface, during kneeling, the pressure which would otherwise fall upon the prominent ridges of the condyles; it also affords leverage to the Quadriceps femoris.

When standing erect in the attitude of 'attention,' the weight of the body falls in front of a line carried across the centres of the knee-joints, and therefore tends to produce over-extension of the articulation; this, however, is prevented by the tension of the anterior cruciate, oblique popliteal, and collateral ligaments.

Muscles producing the movements:

Flexion.—Biceps femoris, Semitendinosus, Semimembranosus, Popliteus, Gracilis, Sartorius, Gastrocnemius, Plantaris.

Extension.—Quadriceps femoris.

Rotation of the leg inwards.—Semitendinosus, Semimembranosus, Gracilis, Sartorius, Popliteus.

Rotation of the leg outwards.—Biceps femoris.

Applied Anatomy.—From a consideration of the construction of the knee-joint, it would at first sight appear to be one of the least secure joints in the body. It is formed between the two longest bones, and therefore the amount of leverage which can be brought to bear upon it is considerable; the articular surfaces are but ill-adapted to each other, and the range of motion which it enjoys is great. All these circumstances tend to render the articulation insecure; nevertheless, on account of the powerful ligaments which bind the bones together, the joint is one of the strongest in the body, and dislocation from traumatism is a rare occurrence. When, on the other hand, the ligaments have been softened or destroyed by disease, partial displacement is liable to occur, and is frequently brought about by the action of the muscles.

One or other of the menisci after being detached may become displaced or nipped. When detached it is either the coronary ligament, or one end of the meniscus that is torn. The attachment of the medial meniscus to the tibial collateral ligament may also be separated. When the meniscus is nipped the inner thin portion is often torn; the torn portion projects between the joint-surfaces and leads to locking of the joint in the semi-flexed position. The accident is produced by a twist of the leg when the knee is flexed, and is accompanied by a sudden pain and fixation of the knee in a flexed position. The meniscus may be displaced either towards the tibial intercondyloid eminence, so that the cartilage becomes lodged in the intercondyloid fossa, or to one side, so that the cartilage projects beyond the margin of the two articular surfaces. The medial meniscus is much more commonly affected than the lateral because (1) it is the more firmly attached to the tibia; (2) during the slight rotation of the joint it moves through a greater interval than the lateral meniscus.

The cruciate ligaments are sometimes ruptured by great violence. When the anterior is torn the tibia can be pushed forwards; when the posterior is torn the tibia can be pulled backwards.

Acute synovitis, the result of traumatism, is of frequent occurrence in the knee-joint. When the cavity is distended with fluid, the swelling shows itself above and at the sides of the patella, reaching about 2·5 cm., occasionally 5 cm. or more, above the patellar surface of the femur, and extending a little higher under the Vastus medialis than under the Vastus lateralis. The lower level of the synovial stratum is just at the level of the head of the tibia.

Excision of the knee-joint is best performed by a horseshoe-shaped incision, starting from one femoral condyle, descending as low as the tuberosity of the tibia, and then carried upwards to the other femoral condyle. The bone ends having been cleared, and in those cases where the operation is performed for tuberculous disease all pulpy tissue having been carefully removed, the section of the femur is first made. This should never include, in children, more than, at the most, two-thirds of the articular surface, otherwise the epiphysial cartilage will be involved, with disastrous results as regards the growth of the limb. Afterwards a thin slice, not more than 1·25 cm., should be removed from the upper end of the tibia. In making this section of the tibia great care is necessary in order to avoid cutting the popliteal vessels which are in contact with the posterior ligament of the joint. If any diseased tissue appears still to be left in the bones, it should be removed with the gouge, rather than by a further section. The most useful position for ankylosis to occur is very slight flexion, but as flexion is difficult to limit it is better to aim at the straight position.

The close relationship of the head of the fibula to the synovial stratum of the knee-joint explains the risk of opening that joint in removing the head of the fibula.

The bursæ about the knee-joint are sometimes the seat of enlargement. The bursa between the front of the patella and the skin is frequently affected in individuals who are in the habit of constantly kneeling, and the condition is then known as 'housemaid's knee.' The bursa beneath the Semimembranosus tendon also occasionally becomes enlarged, and forms a fluctuating swelling at the back of the knee. During extension, the swelling is firm and tense; but during flexion it becomes soft, and, as the bursa often communicates with the synovial cavity of the joint, the fluid it contains can be made to disappear by pressure when the knee is flexed. Extension of septic processes within the joint is apt to occur along the tendon-sheath of the Popliteus, and this may lead to deep-seated suppuration in the popliteal fossa, often associated with septic thrombosis of the popliteal vein.

V. THE TIBIOFIBULAR ARTICULATIONS

The articulations between the tibia and fibula are effected by ligaments which connect the extremities and bodies of the bones. The ligaments may consequently be subdivided into three sets: (1) those of the proximal tibiofibular articulation; (2) the crural interosseous membrane; (3) those of the distal tibiofibular articulation (tibiofibular syndesmosis).

1. The Proximal Tibiofibular Articulation

This articulation (fig. 520) is an arthrodial joint between the lateral condyle of the tibia and the head of the fibula. The contiguous surfaces of the bones

Movements.—The shoulder-joint is capable of flexion, extension, abduction, adduction, circumduction, and rotation.

The most striking peculiarities in this joint are: 1. The large size of the head of the humerus in comparison with the depth of the glenoid cavity, even though the latter is supplemented by the glenoidal labrum. 2. The looseness of the capsule of the joint. 3. The intimate connexion of the capsule with the muscles attached to the tubercles of the humerus. 4. The peculiar relation of the tendon of the long head of the Biceps brachii to the joint.

It is in consequence of the relative sizes of the two articular surfaces, and the looseness of the articular capsule, that the joint enjoys such free movement in all directions. When these movements of the arm are arrested in the shoulder-joint by the contact of the bony surfaces, and by the tension of the fibres of the capsule together with that of the muscles acting as accessory ligaments, the arm can be carried considerably farther by the movements of the scapula, involving, of course, motion at the sternoclavicular and acromioclavicular joints. These joints are therefore to be regarded as accessory to the shoulder-joint (pp. 374 to 377). The extent of the scapular movements is very considerable, especially in extreme elevation of the arm, a movement best accomplished when the arm is thrown somewhat forwards and outwards, because the margin of the head of the humerus is by no means a true circle; the greatest diameter of the head is from the intertubercular groove, downwards, medialwards, and backwards, and the greatest elevation of the arm can be obtained by rolling its articular surface in the direction of this measurement.

The looseness of the capsule is so great that the arm will fall 2 or 3 cm. from the scapula when the muscles are dissected from the capsule, and an opening made in it to counteract the atmospheric pressure. The movements of the joint, therefore, are not regulated by the capsule so much as by the surrounding muscles, an arrangement which 'renders the movements of the joint much more easy than they would otherwise have been, and permits a swinging, pendulum-like vibration of the limb when the muscles are at rest' (Humphry). The fact, also, that in all ordinary positions of the joint the capsule is not put on the stretch, enables the arm to move freely in all directions. Extreme movements are checked by the tension of appropriate portions of the capsule, as well as by the interlocking of the bones. Thus it is said that 'abduction is checked by the contact of the great tuberosity with the upper edge of the glenoid cavity; adduction by the tension of the coraco-humeral ligament' (Beaunis and Bouchard). Cleland * maintains that the limitations of movement at the shoulder-joint are due to the structure of the joint itself, the glenoidal labrum fitting, in different positions of the elevated arm, into the anatomical neck of the humerus.

The scapula is capable of being moved upwards and downwards, and forwards and backwards, and, by a combination of these movements, circumducted on the wall of the chest. The mobility of the scapula is very considerable, and greatly assists the movements of the arm at the shoulder-joint. Thus, in raising the arm from the side, the Deltoideus and Supraspinatus can only lift it to a right angle with the trunk, the further elevation of the limb being effected by the Trapezius and Serratus anterior moving the scapula on the wall of the chest. This mobility is of special importance in ankylosis of the shoulder-joint, the movements of the scapula compensating to a very great extent for the immobility of the joint.

Cathcart † has pointed out that in abducting the arm and raising it above the head, the scapula rotates throughout the whole movement with the exception of a short space at the beginning and at the end; that the humerus moves on the scapula not only while passing from the hanging to the horizontal position, but also in travelling upwards as it approaches the vertical above; that the clavicle moves not only during the second half of the movement but in the first as well, though to a less extent—i.e. the scapula and clavicle are concerned in the first stage as well as in the second; and that the humerus is partly involved in the second as well as chiefly in the first.

The peculiar relations of the tendon of the long head of the Biceps brachii to the shoulder-joint appear to subserve various purposes. In the first place, by its connexion with both the shoulder and elbow the muscle harmonises the action of the two joints, and acts as an elastic ligament during all the movements

* *Journal of Anatomy and Physiology*, vol. i., 1867.

† *Journal of Anatomy and Physiology*, vol. xviii.

The **articular capsule** (fig. 524) surrounds the joint, and its fibrous stratum is attached, above, to the borders of the articular surfaces of the tibia

FIG. 524.—The articular capsule of the left talocrural articulation (distended). Lateral aspect. (From a specimen prepared by J. C. B. Grant.)

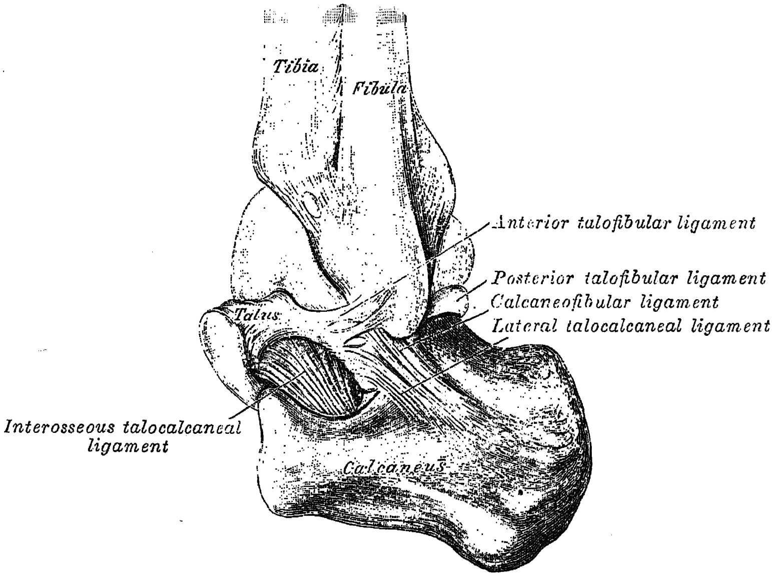
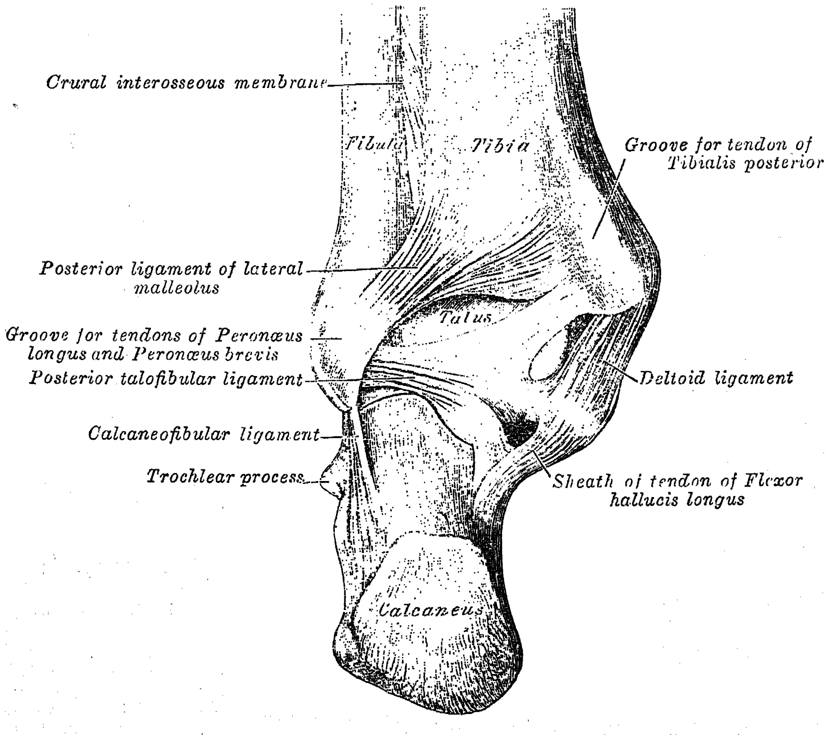


FIG. 525.—The left talocrural articulation. Posterior aspect.

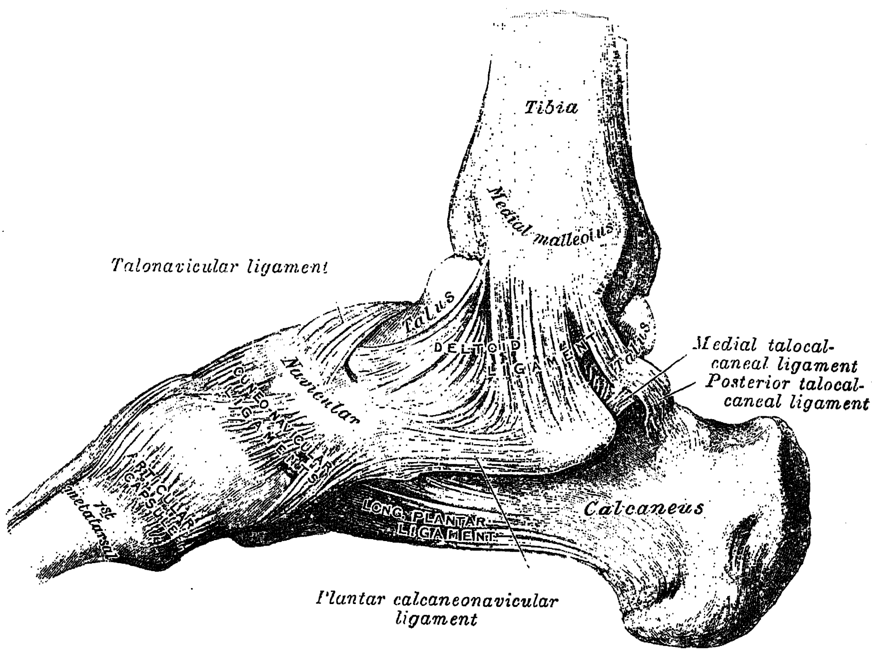


and malleoli, and below, to the talus around its trochlear articular surface. Its anterior part, often termed the *anterior ligament*, is a broad, thin, membranous

layer, attached, above, to the anterior margin of the lower end of the tibia, and below, to the talus, some distance in front of its superior articular surface. It is in relation, in front, with the extensor tendons of the toes, the tendons of the Tibialis anterior and Peronæus tertius, and the anterior tibial vessels and deep peronæal nerve. Its posterior part, often termed the *posterior ligament*, is very thin, and consists principally of transverse fibres. It is attached, above, to the margin of the articular surface of the tibia, blending with the inferior transverse ligament, and below, to the talus behind its superior articular facet. Laterally, it is somewhat thickened, and is attached to the hollow on the medial surface of the lateral malleolus.

The fibrous stratum is lined with a synovial stratum, and the joint-cavity is continued upwards for a short distance between the tibia and fibula.

FIG. 526.—The ligaments of the right ankle and tarsus. Medial aspect.



The **deltoid ligament** (internal lateral ligament) (figs. 525, 526) is a strong, triangular band, attached, above, to the apex and anterior and posterior borders of the medial malleolus. It consists of two sets of fibres, superficial and deep. Of the superficial fibres the anterior (*tibionavicular*) pass forwards to be attached to the tuberosity of the navicular bone, and immediately behind this they blend with the medial margin of the plantar calcaneonavicular ligament; the middle (*calcaneotibial*) descend almost perpendicularly and are fixed into the whole length of the sustentaculum tali of the calcaneus; the posterior fibres (*posterior talotibial*) pass backwards and lateralwards to be attached to the medial side of the talus, and to the prominent tubercle on its posterior surface, medial to the groove for the tendon of the Flexor hallucis longus. The deep fibres (*anterior talotibial*) are fixed, above, to the tip of the medial malleolus, and, below, to the medial surface of the talus. The deltoid ligament is crossed by the tendons of the Tibialis posterior and Flexor digitorum longus.

The **anterior talofibular ligament** (fig. 527) passes from the anterior margin of the fibular malleolus, forwards and medialwards, to the talus, in front of its lateral articular facet.

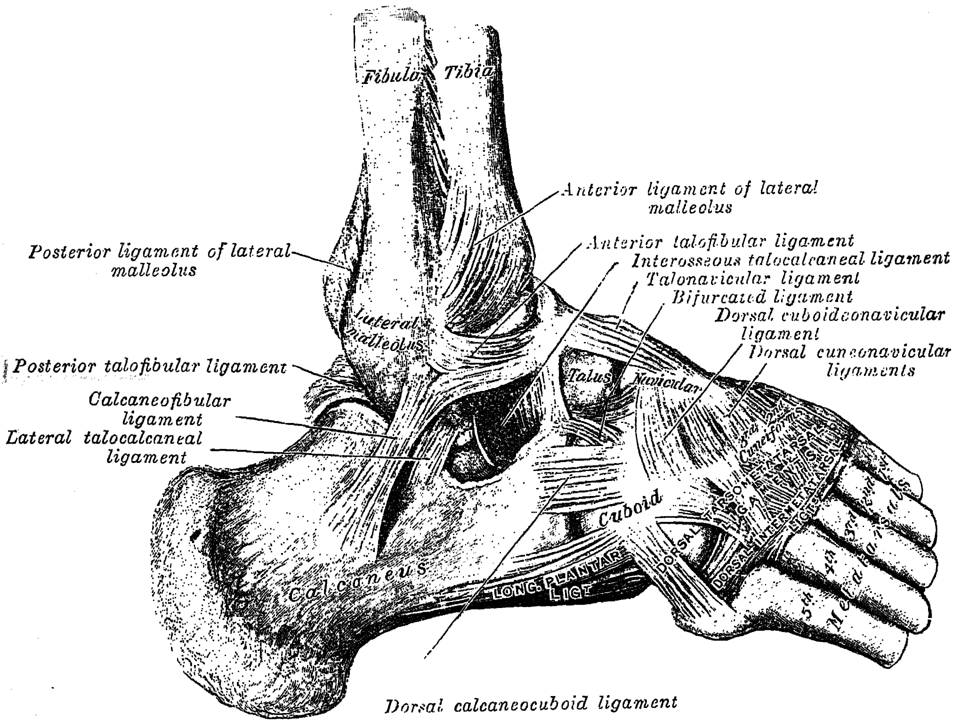
The **posterior talofibular ligament** (fig. 525), strong and deeply seated, runs almost horizontally from the depression at the medial and posterior part of the fibular malleolus to the posterior process of the talus.

The **calcaneofibular ligament** (fig. 527) is a long rounded cord, running from the apex of the fibular malleolus downwards and slightly backwards to a tubercle on the lateral surface of the calcaneus. It is crossed by the tendons of the Peronæi longus et brevis.

The anterior and posterior talofibular and the calcaneofibular ligaments were formerly described as the three fasciculi of the *external lateral ligament* of the ankle-joint.

Relations.—The tendons, vessels, and nerves in relation with the joint are, in front, from the medial side, the Tibialis anterior, Extensor hallucis longus, anterior tibial vessels, deep peronæal nerve, Extensor digitorum longus, and Peronæus tertius; behind, from the medial side, the Tibialis posterior, Flexor digitorum

Fig. 527.—The ligaments of the right ankle and tarsus. Lateral aspect.



longus, posterior tibial vessels, tibial nerve, Flexor hallucis longus; and, in the groove behind the fibular malleolus, the tendons of the Peronæi longus et brevis.

The *arteries* supplying the joint are derived from the malleolar branches of the anterior tibial and from the peronæal.

The *nerves* are derived from the deep peronæal and tibial.

Movements.—When the body is in the erect position, the foot is at right angles to the leg. The movements of the ankle-joint are those of dorsiflexion and extension; dorsiflexion consists in the approximation of the dorsum of the foot to the front of the leg; in extension the heel is drawn up and the toes pointed downwards. The malleoli tightly embrace the talus in all positions of the joint, so that any slight degree of side-to-side movement which may exist is simply due to stretching of the ligaments of the distal talofibular joint, and slight bending of the fibula. The superior articular surface of the talus is broader in front than behind. In dorsiflexion, therefore, greater space is required between the two malleoli. This is obtained by a slight outward rotatory movement of the lower end of the fibula and a stretching of the ligaments of the distal talofibular joint; this lateral movement is facilitated by a slight gliding at the proximal tibiofibular joint, and possibly also by the bending of the body of the fibula. Of the ligaments, the deltoid

is of great power—so much so, that it usually resists a force which fractures the process of bone to which it is attached. Its middle portion, together with the calcaneofibular ligament, binds the bones of the leg firmly to the foot, and resists displacement in every direction. Its anterior and posterior fibres limit extension and flexion of the foot respectively, and the anterior fibres also limit abduction. The posterior talofibular ligament assists the calcaneofibular in resisting the displacement of the foot backwards, and deepens the cavity for the reception of the talus. The anterior talofibular ligament is a security against the displacement of the foot forwards, and limits extension of the joint.

Muscles producing the movements :

Flexion.—Tibialis anterior, Extensor digitorum longus, Extensor hallucis longus, Peronæus tertius.

Extension.—Gastrocnemius, Soleus, Plantaris, Tibialis posterior, Flexor digitorum longus, Flexor hallucis longus, Peronæi longus et brevis.

Applied Anatomy.—As the ankle-joint is a very strong and powerful articulation, displacement of the talus from the tibiofibular mortise is a rare accident, and great force is required to produce it. Nevertheless, dislocation does occasionally occur, either anteroposteriorly or to one or other side. In the latter, which is the more common, fracture is a necessary accompaniment of the injury. The dislocation in these cases is somewhat peculiar, and is not a displacement in a horizontal direction, such as usually occurs in dislocations of ginglymoid joints, but the talus undergoes a partial rotation round an anteroposterior axis drawn through its own centre, so that the superior surface, instead of being directed upwards, is inclined more or less medialwards or lateralwards according to the variety of the displacement.

The ankle-joint is more frequently sprained than any joint in the body, and this may lead to acute synovitis. In these cases, when the synovial sac is distended with fluid, the bulging appears principally in the front of the joint, beneath the anterior tendons, and on either side, between the Tibialis anterior and the deltoid ligament on the medial side, and between the Peronæus tertius and the anterior talofibular ligament laterally. In addition to this, bulging often occurs posteriorly, and a fluctuating swelling may be detected on either side of the tendo calcaneus. A large proportion of so-called 'sprains' of the ankle have been proved by *x*-ray examination to be some variety of fracture about the malleoli, with or without displacement.

When disease or injury of the ankle-joint is likely to lead to ankylosis, the joint is kept dorsiflexed to rather less than a right angle.

VII. THE INTERTARSAL ARTICULATIONS

1. The Talocalcaneal Articulation

There are two articulations between the calcaneus and talus, an anterior and a posterior; the anterior forms part of the talocalcaneonavicular joint, and will be described with that articulation. The posterior or talocalcaneal articulation is formed between the posterior calcaneal facet on the inferior surface of the talus, and the posterior facet on the superior surface of the calcaneus. It is an arthrodial joint, and the two bones are connected by an articular capsule and by anterior, posterior, lateral, medial and interosseous talocalcaneal ligaments.

The **articular capsule** envelops the joint, and consists for the most part of short fibres; it is split up into distinct slips, and between these there is only a weak fibrous investment. It is lined with a synovial stratum, and the joint-cavity does not communicate with any of the other tarsal joints.

The **anterior talocalcaneal ligament** (fig. 530) extends from the inferior and lateral surfaces of the neck of the talus to the superior surface of the calcaneus.

The **posterior talocalcaneal ligament** (fig. 526) connects the lateral tubercle on the posterior surface of the talus with the upper and medial part of the calcaneus; it is a short band, and its fibres radiate from their narrow attachment to the talus.

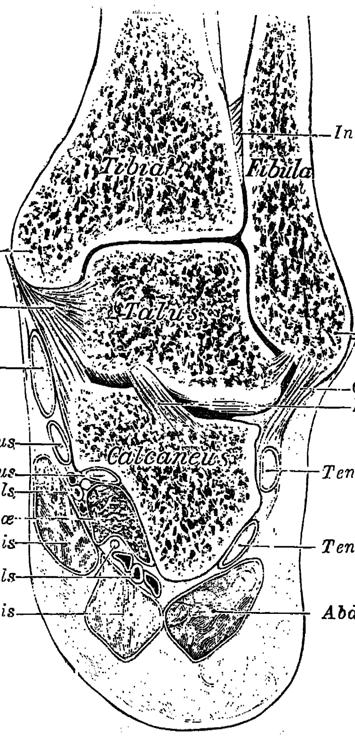
The **lateral talocalcaneal ligament** (figs. 524, 527) is a short, strong fasciculus, passing from the lateral surface of the talus, immediately beneath its fibular facet, to the lateral surface of the calcaneus. It is placed in front of, but on a deeper plane than, the calcaneofibular ligament, with the fibres of which it is parallel.

The **medial talocalcaneal ligament** connects the medial tubercle on the posterior surface of the talus with the back of the sustentaculum tali. Its fibres blend with those of the plantar calcaneonavicular ligament.

The **interosseous talocalcaneal ligament** (figs. 524, 528) is very thick and strong, and forms the chief bond of union between the bones. It is, in fact, a portion of the united capsules of the talocalcaneonavicular and the talocalcaneal joints, and consists of two partially united layers of fibres, one belonging to the former and the other to the latter joint. It is attached, above, to the sulcus tali; below, to the sulcus calcanei.

Movements.—The movements permitted between the talus and calcaneus are limited to gliding of the one bone on the other, backwards and forwards and from side to side.

FIG. 528.—A coronal section through the right talocrural and talocalcaneal joints.



2. The Talocalcaneonavicular Articulation

This articulation is an arthrodial joint: the rounded head of the talus being received into the concavity formed by the posterior surface of the navicular bone, the anterior articular surface of the calcaneus, and the upper surface of the plantar calcaneonavicular ligament. There are two ligaments in this joint; the articular capsule and the talonavicular.

The **articular capsule** is imperfectly developed except posteriorly, where it is considerably thickened and forms, with a part of the capsule of the talocalcaneal joint, the strong interosseous ligament which fills the sinus tarsi formed by the opposing sulci on the calcaneus and talus, as mentioned above.

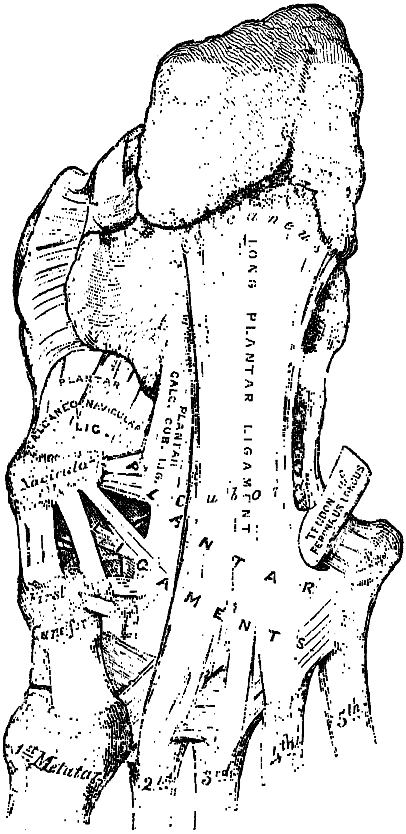
The **talonavicular ligament** (fig. 526) is a broad, thin band, connecting the neck of the talus to the dorsal surface of the navicular bone; it is covered with the extensor tendons. The plantar calcaneonavicular ligament supplies the place of a plantar ligament for this joint.

Movements.—This articulation permits of a considerable range of gliding movements.

3. The Calcaneocuboid Articulation

The articular surfaces of the calcaneocuboid joint are somewhat saddle-shaped. The ligaments of the joint are: the articular capsule, the dorsal calcaneocuboid, the calcaneocuboid portion of the bifurcated ligament, the long plantar, and the plantar calcaneocuboid.

Fig. 529.—The ligaments of the plantar surface of the right foot.



The **articular capsule** contains certain bands, which form the other ligaments of the joint. Its synovial stratum is distinct from that of the other tarsal articulations (fig. 531).

The **dorsal calcaneocuboid ligament** (fig. 527) is a thin but broad fasciculus, which passes between the contiguous surfaces of the calcaneus and the cuboid bone, on the dorsal surface of the joint.

The **bifurcated ligament** (figs. 527, 530) is a strong band attached behind to the deep hollow on the upper surface of the calcaneus and dividing in front in a Y-shaped manner into a calcaneocuboid and a calcaneonavicular part. The *calcaneocuboid part* is fixed to the medial side of the cuboid bone and forms one of the principal bonds between the first and second rows of the tarsal bones. The *calcaneonavicular part* is attached to the lateral side of the navicular bone.

The **long plantar ligament** (fig. 529), the longest of the tarsal ligaments, is attached behind to the plantar surface of the calcaneus in front of the tuberosity, and in front to the tuberosity on the plantar surface of the cuboid bone, the more superficial fibres being continued forwards to the bases of the second, third, and fourth metatarsal bones. This ligament converts the groove on the plantar surface of the cuboid bone into a canal for the tendon of the Peronæus longus.

The **plantar calcaneocuboid ligament** (short plantar ligament) (fig. 529) lies nearer to the bones than the preceding, from which it is separated by a little areolar tissue. It is a short but wide band of great strength, and extends from the tubercle and the depression in front of it, on the fore part of the plantar surface of the calcaneus, to the plantar surface of the cuboid bone behind the peronæal groove.

Movements.—The movements permitted between the calcaneus and the cuboid bone are limited to slight gliding of the bones upon each other.

The *transverse tarsal joint* is formed by the articulation of the calcaneus with the cuboid bone, and the articulation of the talus with the navicular bone. The movement which takes place in this joint is more extensive than that in the other tarsal joints, and consists of a sort of rotation by means of which the foot may be slightly flexed or extended, the sole being at the same time carried medialwards (inverted) or lateralwards (everted).

Muscles producing the movements :

Inversion.—Tibialis anterior, Tibialis posterior.

Eversion.—Peronæus longus.

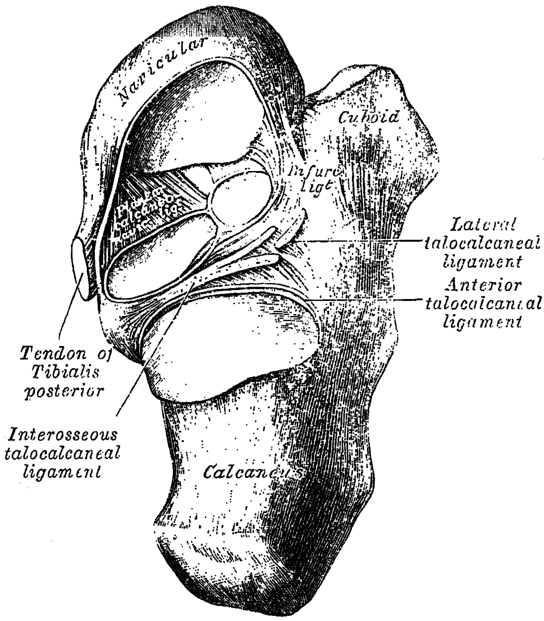
4. The Ligaments connecting the Calcaneus and Navicular

Though the calcaneus and the navicular bone do not directly articulate, they are connected by two ligaments: the calcaneonavicular part of the bifurcated, and the plantar calcaneonavicular.

The **calcaneonavicular part of the bifurcated ligament** is described on p. 426.

The **plantar calcaneonavicular ligament** (fig. 530) is a broad, thick band connecting the anterior margin of the sustentaculum tali of the calcaneus to the plantar surface of the navicular bone. This ligament not only unites the calcaneus with the navicular bone, but supports the head of the talus, forming part of the articular cavity in which it is received. The *dorsal surface* of the ligament presents a fibrocartilaginous facet, lined with the synovial stratum, and upon this a portion of the head of the talus rests. Its *plantar surface* is supported by the tendon of the Tibialis posterior; its *medial border* is blended with the anterior part of the deltoid ligament of the ankle-joint. The plantar calcaneonavicular and plantar calcaneocuboid ligaments together form the *deep ligament* of the tarsus.

Fig. 530.—The right talocalcaneal and talocalcaneonavicular articulations, exposed by removing the talus. Superior aspect.



Applied Anatomy. — The plantar calcaneonavicular ligament, by supporting the head of the talus, is concerned in maintaining the arch of the foot. When it yields the head of the talus is pressed downwards, medialwards, and forwards by the weight of the body, and the foot becomes flattened, expanded, and turned lateralwards, and exhibits the condition known as *flat-foot*. This ligament contains a considerable amount of elastic tissue, so as to give elasticity to the arch and spring to the foot; hence it is sometimes called the 'spring' ligament. It is supported, on its plantar surface, by the tendon of the Tibialis posterior, which spreads out at its insertion into a number of fasciculi, to be attached to most of the tarsal and metatarsal bones. This prevents undue stretching of the ligament, and is a protection against the occurrence of flat-foot; hence muscular weakness is, in most cases, the primary cause of the deformity.

5. The Cuneonavicular Articulation

The navicular bone is connected to the three cuneiform bones by dorsal and plantar ligaments.

The **dorsal ligaments** are three small fasciculi, one attached to each of the cuneiform bones. The fasciculus connecting the navicular bone with the first cuneiform bone is continuous round the medial side of the articulation with the plantar ligament which unites these two bones.

The **plantar ligaments** have a similar arrangement to the dorsal, and are strengthened by slips from the tendon of the Tibialis posterior.

Movements.—Gliding movements are permitted between the navicular and cuneiform bones.

6. The Cuboideonavicular Articulation

The cuboid bone is connected with the navicular bone by dorsal, plantar, and interosseous ligaments.

The **dorsal ligament** extends obliquely forwards and lateralwards, while the **plantar** passes nearly transversely from the cuboid bone to the navicular bone

The **interosseous ligament** consists of strong transverse fibres, and connects the rough non-articular portions of the adjacent surfaces of the two bones.

Movements.—The movements permitted between the navicular and cuboid bones are limited to a slight gliding upon each other.

7. The Intercuneiform and Cuneocuboid Articulations

The three cuneiform bones and the cuboid bone are connected together by dorsal, plantar, and interosseous ligaments.

The **dorsal and plantar ligaments** each consist of three transverse bands : one connects the first and second cuneiform bones, another the second and third cuneiform bones, and another the third cuneiform and cuboid bones. The plantar ligaments are strengthened by slips from the tendon of the Tibialis posterior.

The **interosseous ligaments** connect the rough non-articular portions of the adjacent surfaces of the bones.

Movements.—The movements permitted between these bones are limited to a slight gliding upon each other.

Applied Anatomy.—In spite of the great strength of the ligaments which connect the tarsal bones together, dislocation at some of the tarsal joints does occasionally occur. When this takes place, it is most commonly in connexion with the talus; for not only may this bone be dislocated from the tibia and fibula at the ankle-joint, but the other bones may be dislocated from it, the talus remaining *in situ* in the tibiofibular mortise. This constitutes what is known as the *subtalar* dislocation. Or, again, the talus may be dislocated from all its connexions—from the tibia and fibula above, the calcaneus below, and the navicular in front—and may even undergo a rotation, on either a vertical or a horizontal axis. In the former case the long axis of the bone is directed across the joint, so that the head faces the articular surface on one or other malleolus; in the latter, the collateral surfaces are directed upwards and downwards, so that the superior surface faces to one or the other side. Reduction in these cases is often very difficult or impossible, and the displaced talus may require removal by open operation. Dislocation may also occur at the transverse tarsal joint, the anterior tarsal bones being luxated from the talus and calcaneus. The other tarsal bones are occasionally, though rarely, dislocated from their connexions.

The talus is sometimes removed to remedy certain types of club-foot. The incision is made between the tendons of the Peronæus tertius and Peronæus brevis; the anterior and posterior talofibular and the calcaneofibular ligaments are divided, and the ankle-joint freely opened. In separating the medial side of the talus, the deltoid ligament and the sheath of the Flexor hallucis longus must be divided close to the bone.

VIII. THE TARSOMETATARSAL ARTICULATIONS

These are arthrodial joints. The first metatarsal bone articulates with the first cuneiform bone ; the second is deeply wedged in between the first and third cuneiform bones, articulating by its base with the second cuneiform bone ; the third articulates with the third cuneiform bone ; the fourth, with the cuboid and third cuneiform bones ; and the fifth with the cuboid bone. The bones are connected by dorsal, plantar, and interosseous ligaments.

The **dorsal ligaments** are strong, flat bands. The first metatarsal is joined to the first cuneiform bone by an articular capsule ; the second metatarsal receives three bands, one from each cuneiform bone ; the third, one from the third cuneiform bone ; the fourth, one from the third cuneiform bone and another from the cuboid bone ; and the fifth, one from the cuboid bone.

The **plantar ligaments** consist of longitudinal and oblique bands, disposed with less regularity than the dorsal ligaments. Those for the first and second

metatarsal bones are the strongest ; the second and third metatarsal bones are joined by oblique bands to the first cuneiform bone ; the fourth and fifth metatarsal bones are connected by a few fibres to the cuboid bone.

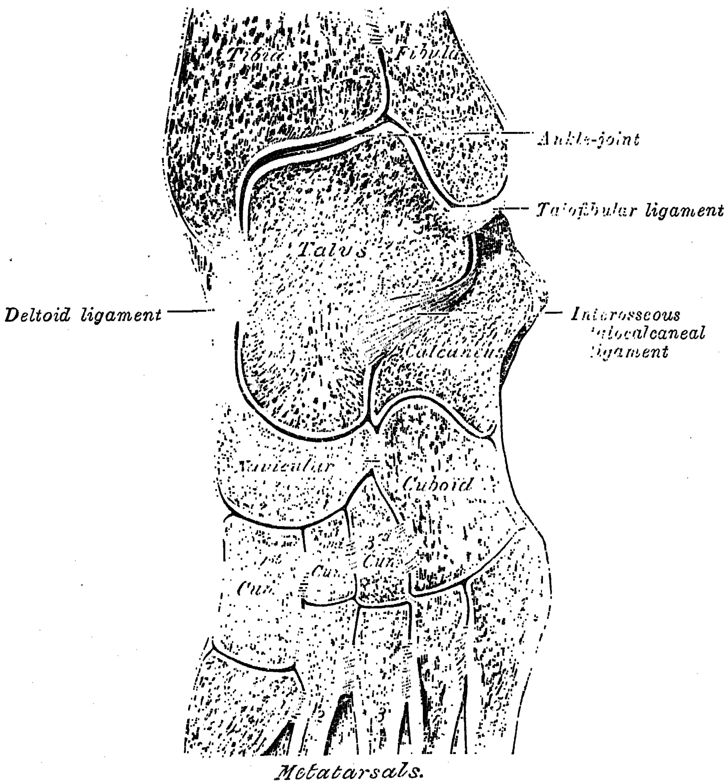
The **interosseous ligaments** are three in number. The first is the strongest and passes from the lateral surface of the first cuneiform bone to the adjacent angle of the second metatarsal bone. The second connects the third cuneiform bone with the adjacent angle of the second metatarsal bone. The third connects the lateral angle of the third cuneiform bone with the adjacent side of the base of the third metatarsal bone.

Movements.—The movements permitted between the tarsal and metatarsal bones are limited to slight gliding of the bones upon each other.

IX. THE INTERMETATARSAL ARTICULATIONS

The base of the first metatarsal bone is not connected with that of the second by any ligaments ; in this respect the great toe resembles the thumb.

FIG. 531.—An oblique section through the left intertarsal and tarsometatarsal articulations, showing the synovial cavities.



The bases of the second, third, fourth, and fifth metatarsal bones are connected by dorsal, plantar, and interosseous ligaments.

The heads of all the metatarsal bones are connected by the transverse metatarsal ligament.

The **dorsal and plantar ligaments** pass transversely between the bases of the adjacent bones.

The **interosseous ligaments** consist of strong transverse fibres which connect the rough non-articular portions of the adjacent surfaces.

The **transverse metatarsal ligament** is a narrow band which runs across and connects together the heads of all the metatarsal bones ; it is blended

anteriorly with the accessory plantar ligaments of the metatarsophalangeal articulations. Its plantar surface is concave where the flexor tendons run below it; above it the tendons of the Interossei pass to their insertions. It differs from the transverse metacarpal ligament in that it connects the first metatarsal to the others.

Movements.—The movements permitted between the tarsal ends of the metatarsal bones are limited to a slight gliding of the articular surfaces one upon another.

The **synovial cavities** (fig. 531) present in the articulations of the tarsus and metatarsus are six in number: one for the talocalcaneal articulation; a second for the talocalcaneonavicular articulation; a third for the calcaneocuboid articulation; a fourth for the cuneonavicular, intercuneiform, and cuneocuboid articulations, the articulations of the second and third cuneiform bones with the bases of the second and third metatarsal bones, and the adjacent surfaces of the bases of the second, third, and fourth metatarsal bones; a fifth for the first cuneiform bone with the metatarsal bone of the great toe; and a sixth, for the articulation of the cuboid bone with the fourth and fifth metatarsal bones. A small synovial cavity is sometimes found between the contiguous surfaces of the navicular and cuboid bones; it may communicate with that between the cuboid and third cuneiform bones.

X. THE METATARSOPHALANGEAL ARTICULATIONS

The metatarsophalangeal articulations are of the condyloid kind, formed by the reception of the rounded heads of the metatarsal bones in shallow cavities on the bases of the first phalanges.

The ligaments are the accessory plantar and collateral.

The **accessory plantar ligaments** (glenoid ligaments of Cruveilhier) are thick, dense, fibrous structures. They are placed on the plantar surfaces of the joints in the intervals between the collateral ligaments, to which they are connected; they are loosely united to the metatarsal bones, but are firmly fixed to the bases of the first phalanges. Their plantar surfaces are intimately blended with the transverse metatarsal ligament, and grooved for the flexor tendons, the fibrous sheaths of which are connected to the sides of the grooves; the deep surfaces of the ligaments form parts of the articular facets for the heads of the metatarsal bones.

The **collateral ligaments** are two strong, rounded cords, placed on the sides of the joints; each is attached by one end to the posterior tubercle on the side of the head of the metatarsal bone, and by the other to the corresponding side of the base of the phalanx.

The place of *dorsal ligaments* is supplied by the extensor tendons on the dorsal surfaces of the joints.

Movements.—The movements permitted in the metatarsophalangeal articulations are flexion, extension, adduction, abduction and circumduction.

Muscles producing the movements:

Flexion.—Flexores digitorum longus et brevis, Quadratus plantæ, Lumbricales, Interossei dorsales et plantares, Flexores hallucis longus et brevis, Flexor digiti quinti proprius.

Extension.—Extensores digitorum longus et brevis, Extensor hallucis longus.

Adduction.—Interossei plantares, Adductor hallucis, long flexors of toes.

Abduction.—Interossei dorsales, Abductor hallucis, Abductor digiti quinti.

XI. THE ARTICULATIONS OF THE DIGITS

The interphalangeal articulations are hinge-joints, and each has a plantar and two collateral ligaments.

The arrangement of these ligaments is similar to that in the metatarsophalangeal articulations: the extensor tendons supply the places of dorsal ligaments.

Movements.—The only movements permitted in the joints of the digits are flexion and extension; these movements are more extensive between the first and second phalanges than between the second and third. The amount of flexion is very considerable, but extension is limited by the accessory plantar ligaments.

Muscles producing the movements :

Flexion.—Flexores digitorum longus et brevis, Quadratus plantæ, Flexor hallucis longus.

Extension.—Lumbricales, Interossei dorsales et plantares, Extensor hallucis longus, Extensores digitorum longus et brevis.

Applied Anatomy.—When the head of the first metatarsal bone is removed for the enlargement which occurs in chronic arthritis, the sesamoid bones in the Flexor hallucis brevis should not be removed, since they form a protection to the new joint. The bursa over the head of the metatarsal bone is used in this operation to make the new joint-cavity.

The Arches of the Foot

In order that the foot may support the weight of the body in the erect posture with the least expenditure of material, it is constructed of a series of arches formed by the tarsal and metatarsal bones, and strengthened by the ligaments, tendons and fasciæ of the foot.

The main arches are the anteroposterior arches, which may be regarded as divisible into two types—a medial and a lateral.

Fig. 532.—The skeleton of the left foot. Medial aspect.

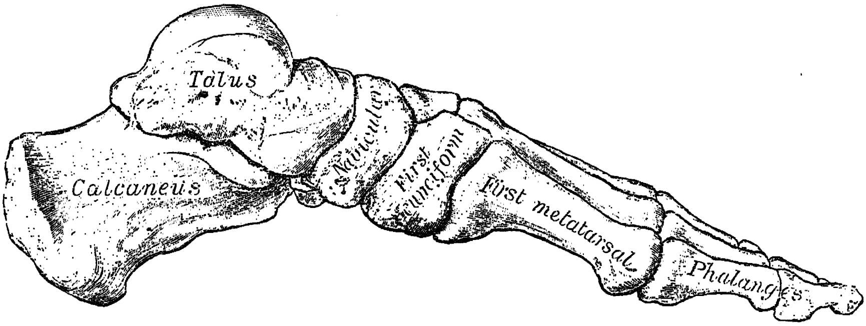
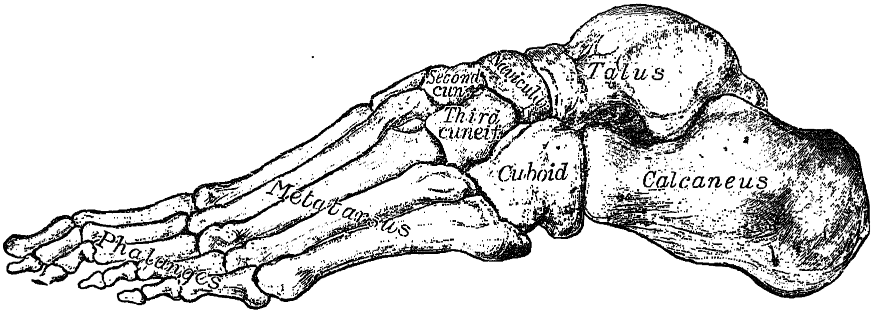


Fig. 533.—The skeleton of the left foot. Lateral aspect.



The *medial arch* (fig. 532) is made up by the calcaneus, the talus, the navicular, the three cuneiform, and the first, second, and third metatarsal bones. Its summit is at the superior articular surface of the talus, and its two extremities or piers, on which it rests in standing, are the tuberosity on the plantar surface of the calcaneus posteriorly, and the heads of the first, second, and third metatarsal bones anteriorly. The chief characteristic of this arch is its elasticity, due to its height and to the number of joints between its component parts. Its weakest part, i.e. the part most liable to yield from over-pressure, is the joint between the talus and the navicular bone, but this is braced by the plantar calcaneonavicular ligament, which is elastic and is thus able quickly to restore the arch when the disturbing force is removed. This ligament is strengthened medially by blending with the deltoid ligament of the ankle-joint, and is supported inferiorly by the tendon of

the Tibialis posterior. The arch is further supported by the plantar aponeurosis, by the small muscles in the sole of the foot, by the tendon of the Tibialis anterior, and by the ligaments of all the articulations involved.

The *lateral arch* (fig. 533) is composed of the calcaneus, the cuboid, and the fourth and fifth metatarsal bones. Its summit is at the talocalcaneal articulation, and its chief joint is the calcaneocuboid, which possesses a special mechanism for locking, and allows only a limited movement. The most marked features of this arch are its solidity and its slight elevation; two strong ligaments, the long plantar and the plantar calcaneocuboid, the tendon of the Peronæus longus, the extensor tendons, and the short muscles of the little toe, preserve its integrity.

In addition to the longitudinal arches the foot presents a series of transverse arches. At the posterior part of the metatarsus and the anterior part of the tarsus the arches are complete, but in the middle of the tarsus they present more the characters of half-domes the concavities of which are directed downwards and medialwards, so that when the medial borders of the feet are placed in apposition a complete tarsal dome is formed. The transverse arches are strengthened by the interosseous, plantar, and dorsal ligaments, by the short muscles of the first and fifth toes (especially the transverse head of the Adductor hallucis), and by the Peronæus longus, the tendon of which stretches between the piers of the arches.

Applied Anatomy.—Pes planus or flat-foot is a very common deformity due to the disappearance of the arches of the foot, from subsidence dependent on stretching of the plantar ligaments. In its early stages before the deformity is marked it is accompanied by considerable pain from pressure on the plantar nerves, but when the condition is fully formed and the head of the talus has descended completely, the condition is painless but irremediable.

The stretching of the ligaments in this condition is most often due to muscular weakness in young adults who may have to stand for long periods daily. The deep muscles, especially the posterior tibial group, by their tonicity are the most potent in maintaining the longitudinal arch, and when overtired they relax and throw the strain on the plantar ligaments which yield secondarily. All three posterior tibial muscles are effective in thus supporting the longitudinal arch, but perhaps the most important one is the Flexor hallucis longus which normally stretches like a bow-string across the whole antero-posterior length of the arch.

The transverse arch subsequently disappears, this having been largely held up by the Peronæus longus. In the treatment of this static form of flat-foot, muscular rest is essential in the early stages, as once the ligamentous tissues are stretched, they are unable to return to their original condition.

There are, however, other forms of flat-foot, viz. the congenital, and the paralytic (due to affections of the nerve-centres supplying the post-tibial group of muscles); those due to inflammation of the tarsal joints and those following injuries to the tarsus and metatarsus. If in the two later forms the patient put his weight on the foot before the normal condition has been fully established, pes planus is certain to result, and the arches will not be capable of restoration subsequently.

Pes cavus, the opposite of pes planus, is usually due to some contracture of the posterior tibial group in certain affections of the medulla spinalis. It is also commonly seen in association with talipes equinus or equinovarus, and here the longitudinal arching of the foot is greatly increased, with contraction of the plantar aponeurosis which in some instances becomes very pronounced.

MYOLOGY*

THE **muscles** are connected with the bones, cartilages, ligaments, and skin, either directly, or through the intervention of fibrous structures called tendons or aponeuroses. Where a muscle is attached to bone or cartilage, the fibres end in blunt extremities upon the periosteum or perichondrium, and do not come into direct relation with the osseous or cartilaginous tissue. Where muscles are connected with the skin, they lie as a flattened layer beneath it, and are united with its areolar tissue by larger or smaller bundles of fibres.

Muscles vary in their form. In the limbs, they are of considerable length, especially the more superficial ones; they surround the bones, and constitute an important protection to the joints. In the trunk, they are broad and flattened, and assist in forming the walls of the trunk cavities. Hence the reason of the terms, *long, broad, short,* &c., used in the description of muscles.

There is considerable variation in the arrangement of the fibres of certain muscles with reference to the tendons to which they are attached. In some muscles the fibres are parallel and run directly from their origin to their insertion; these are quadrilateral muscles, such as the Thyreohyoideus. A modification of these is found in the fusiform muscles, in which the fibres are not quite parallel, but slightly curved, so that the muscle tapers at either end; in their mode of action, however, they resemble the quadrilateral muscles. In other muscles the fibres arise by a broad origin and converge to a narrow or pointed insertion; this arrangement is found in the triangular muscles—e.g. the Temporalis. In some muscles, which otherwise would belong to the quadrilateral or triangular type, the origin and insertion are not in the same plane, the plane of the line of origin intersecting that of the line of insertion: such is the case in the Pectineus. In some muscles (e.g. the Peronæi) the fibres are oblique and are attached to one side of a tendon; such muscles are termed unipennate. A modification of this condition is found where oblique fibres are fixed to both sides of a central tendon; such muscles are called bipennate, and an example is afforded in the Rectus femoris. Finally, there are muscles in which the fibres are arranged in curved bundles in one or more planes, as in the Sphincters. The arrangement of the fibres is of considerable importance in respect to the relative strength and range of movement of the muscle. Those muscles where the fibres are long and few in number have great range, but diminished strength; where, on the other hand, the fibres are short and more numerous, there is great power, but lessened range.

The names applied to the various muscles have been derived: 1, from their situation, as the Tibialis anterior, Tibialis posterior; 2, from their direction, as the Rectus abdominis, Obliqui capitis, Transversus abdominis; 3, from their uses, as Flexors, Extensors, Abductors, &c.; 4, from their shape, as the Deltoideus, Rhomboideus; 5, from the number of their divisions, as the Biceps, and Triceps; 6, from their attachment, as the Sternocleidomastoideus, Sternohyoideus, Sternothyreoideus.

* The muscles and fasciæ are described conjointly, in order that the student may consider the arrangement of the latter in his dissection of the former. It is rare for the student of anatomy in this country to have the opportunity of dissecting the fasciæ separately; and it is for this reason, as well as from the close connexion that exists between the muscles and their investing sheaths, that they are considered together. Some general observations are first made on the anatomy of the muscles and fasciæ, the special descriptions being given in connexion with the different regions.

In the description of a muscle, the term *origin* is meant to imply its more fixed or central attachment; and the term *insertion* the movable point to which the force of the muscle is applied; but the origin is absolutely fixed in only a small number of muscles, such as those of the face which are attached by one end to immovable bones, and by the other to the movable skin. Most of the muscles can be made to act from either end.

In the dissection of the muscles, attention should be directed to the *origin, insertion,* and *actions* of each, and to their more important *relations* with surrounding parts. While accurate knowledge of the points of attachment of the muscles is of great importance in determining their actions, it is not to be regarded as conclusive. The action of the muscle deduced from its attachments, or even by pulling on it in the dead subject, is not necessarily its action in the living. By pulling, for example, on the Brachioradialis in the cadaver the hand may be slightly supinated when in the prone position and slightly pronated when in the supine position, but there is no evidence that these actions are performed by the muscle during life. It is impossible for an individual to throw into action any one muscle; in other words, movements, not muscles, are represented in the central nervous system. To carry out a movement a definite combination of muscles is called into play, and the individual has no power either to leave out a muscle from this combination, or to add one to it. One (or more) muscle of the combination is the chief moving force; when this muscle passes over more than one joint, other muscles (synergic muscles) come into play to inhibit the movements not required; a third set of muscles (fixation muscles) fix the limb—i.e. in the case of the limb-movements—and also prevent disturbances of the equilibrium of the body generally. As an example, the movement of the closing of the fist may be considered: (1) the prime movers are the Flexores digitorum, Flexor pollicis longus, and the small muscles of the thumb; (2) the synergic muscles are the Extensores carpi, which prevent flexion of the wrist; while (3) the fixation muscles are the Biceps and Triceps brachii, which steady the elbow and shoulder. A further point which must be borne in mind in considering the actions of muscles is that in certain positions a movement can be effected by gravity, and in such a case the muscles acting are the antagonists of those which might be supposed to be in action. Thus in flexing the trunk when no resistance is interposed the Sacrospinales contract to regulate the action of gravity, and the Recti abdominis are relaxed.*

The minute anatomy of muscular tissue is described on pp. 29 to 33.

Applied Anatomy.—By a consideration of the actions of the muscles, the surgeon is able to explain the causes of displacement in various forms of fracture, and the causes which produce distortion in various deformities, and, consequently, to adopt appropriate treatment in each case. The relations, also, of some of the muscles, especially those in immediate apposition with the large blood-vessels, and the surface markings they produce, should be remembered, as they form useful guides in the application of ligatures to those vessels. Degeneration of muscular tissue is important clinically, and is met with in two main conditions. In one, the degeneration is myopathic, or primary in the muscles themselves; in the other it is neuropathic, or secondary to some lesion of the nervous system—a hæmorrhage into the brain, for example, or injury or inflammation of some part of the medulla spinalis or peripheral nerves. In either case more or less paralysis and atrophy of the affected muscles result. When the degeneration begins primarily in the muscles, however, it often happens that though the muscle-fibres waste away, their place is taken by fibrous and fatty tissue to such an extent that the affected muscles increase in volume, and actually appear to hypertrophy.

Ossification of muscular tissue as a result of repeated strain or injury is not infrequent. It is oftenest found about the tendon of the Adductor longus in horsemen, in the Pectoralis major and Deltoideus of soldiers, or in the tendon of the Brachialis after dislocation of the elbow. It may take the form of exostoses firmly fixed to the bone—e.g. 'rider's bone' on the femur—or of layers or spicules of bone lying in the muscles or their fasciæ and tendons. Busse states that these bony deposits are preceded by a hæmorrhagic myositis due to injury, the effused blood organising and being finally converted into bone. In the rarer disease, progressive myositis ossificans, there is an unexplained tendency for practically any of the voluntary muscles to become converted into solid and brittle bony masses which are completely rigid.

* Consult in this connexion 'Muscular Movements and their representation in the Central Nervous System,' by C. E. Beevor (1903), 'The Action of Muscles,' by W. Colin Mackenzie (1918), 'The principles of Anatomy as seen in the hand,' F. Wood Jones (1920).

THE TENDONS, APONEUROSES, AND FASCIÆ

The **tendons** are white, glistening cords, varying in length and thickness, and devoid of elasticity. They consist almost entirely of white fibrous tissue, the fibrils of which have an undulating course parallel with each other and are firmly united together. They are very sparingly supplied with blood-vessels, the smaller tendons presenting in their interior no trace of them. Nerves supplying tendons end in what are known as neurotendinous spindles or organs of Golgi; these are described with the organs of the senses.

The **aponeuroses** are flattened or ribbon-shaped tendons, of a pearly-white colour, iridescent and glistening; they are only sparingly supplied with blood-vessels.

The tendons and aponeuroses connect the muscles with the movable structures, such as the bones and cartilages. Where the end of a muscle is continued directly into a tendon, the line of junction between the two is usually well-defined, but where the muscle meets the tendon obliquely, bundles of tendon fibres generally run for a variable distance into the substance of the muscle, so that the line of junction is irregular. Microscopic examination shows that, in either case, the tendon is subdivided into small bundles, corresponding in size and number with the fibres of the muscle. Each muscular fibre ends in a more or less rounded extremity covered by sarcolemma, and the fibres of each tendon bundle are intimately united with the sarcolemma covering the end of the muscular fibre. The mode of union is well shown when the muscle fibre has shrunk inside its sarcolemma.

The **fasciæ** are fibro-areolar or aponeurotic laminæ, of variable thickness and strength, found in all regions of the body, investing the softer and more delicate organs. During the process of development many of the cells of the mesoderm are differentiated into bones, muscles, vessels, &c.; the cells of the mesoderm which are not so utilised form an investment for these structures and are differentiated into the true skin and the fasciæ of the body. The fasciæ are subdivided into superficial and deep.

The *superficial fascia* is found immediately beneath the integument over almost the entire surface of the body. It connects the skin to the subjacent parts, and consists of fibro-areolar tissue, containing in its meshes pellicles of fat in varying quantity. It varies in thickness in different parts of the body; in the groin it is so thick that it may be subdivided into several laminæ. Beneath the fatty layer there is generally another layer of superficial fascia, almost devoid of adipose tissue, in which the trunks of the subcutaneous vessels and nerves and the superficial lymph-glands are found. Certain cutaneous muscles are situated in the superficial fascia, e.g. the Platysma and the muscles of the face. The superficial fascia is most distinct at the lower part of the abdomen, perinæum, and extremities; it is very thin in those regions where muscular fibres are inserted into the integument, as on the side of the neck, in the face, and around the anus. It is very dense in the scalp, palms of the hands, and soles of the feet, forming a fibrofatty layer, which binds the integument firmly to the underlying structures. It facilitates the movement of the skin, serves as a soft nidus for the passage of vessels and nerves to the skin, and retains the warmth of the body, since the fat contained in its areolæ is a bad conductor of heat.

The *deep fascia* is a dense, inelastic membrane, forming sheaths for the muscles, and in some cases affording them broad surfaces for attachment. It consists of shining tendinous fibres, placed parallel with one another, and connected together by other fibres disposed in a rectilinear manner. It forms a strong investment which not only binds down collectively the muscles in each region, but gives a separate sheath to each, as well as to the vessels and nerves. It assists the muscles in their actions by the degree of tension and pressure it makes upon their surfaces; in certain situations the degree of tension and pressure is regulated by muscles, as, for instance, by the Tensor fasciæ latæ and Glutæus maximus in the thigh, and the Palmaris longus in the hand. In the limbs, the fascia not only invests the limb, but gives off septa which separate the various muscles, and are attached to the periosteum: these prolongations of fasciæ are usually spoken of as intermuscular septa.

The fasciæ and muscles may be grouped into those of the head and neck; of the trunk; of the upper extremity; and of the lower extremity.

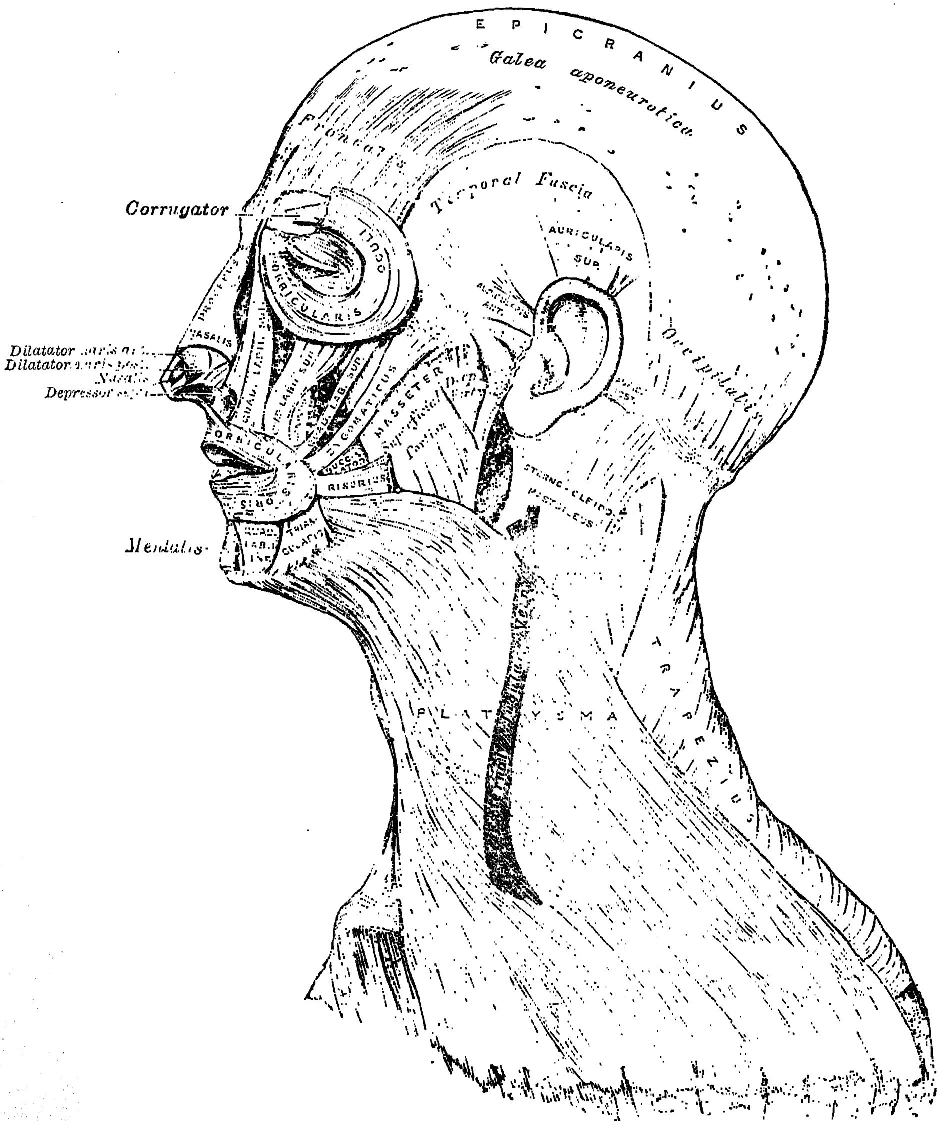
THE FASCIA AND MUSCLES OF THE HEAD

I. The Muscle of the Scalp

Epicranius

The **superficial fascia** in the cranial region is a firm, fibrofatty layer, intimately adherent to the integument, and to the Epicranius and its tendinous aponeurosis; behind, it is continuous with the superficial fascia at the back of the neck; laterally, is prolonged over the temporal fascia.

Fig. 534.—The muscles of the scalp and face. Left lateral aspect.



The **Epicranius** (Occipitofrontalis) (fig. 534) is a broad, musculofibrous layer, which covers the vertex of the skull on either side, from the occipital

bone to the eyebrow. It consists of two parts, the Occipitalis and the Frontalis, connected by an intervening aponeurosis, the galea aponeurotica.

The *Occipitalis*, thin and quadrilateral in form, arises by tendinous fibres from the lateral two-thirds of the highest nuchal line of the occipital bone, and from the mastoid part of the temporal bone. It ends in the galea aponeurotica.

The *Frontalis* is thin, of a quadrilateral form, and intimately adherent to the superficial fascia. It is broader than the Occipitalis and its fibres are longer and paler in colour. It has no bony attachments. Its medial fibres are continuous with those of the Procerus; its intermediate fibres blend with the Corrugator and Orbicularis oculi; and its lateral fibres are also blended with the latter muscle over the zygomatic process of the frontal bone. From these attachments the fibres are directed upwards, and join the galea aponeurotica in front of the coronal suture. The medial margins of the Frontales are joined together for some distance above the root of the nose; but between the Occipitales there is a considerable, though variable, interval, occupied by the galea aponeurotica.

The galea aponeurotica (epicranial aponeurosis) covers the upper part of the cranium; behind, it is attached, in the interval between the Occipitales, to the external occipital protuberance and highest nuchal line of the occipital bone; in front, it forms a short and narrow prolongation between the Frontales. On either side it gives origin to the Auriculares anterior et superior; in this situation it loses its aponeurotic character, and is continued over the temporal fascia to the zygomatic arch. It is closely united to the integument by the firm, fibrofatty superficial fascia: it is connected to the pericranium by loose cellular tissue, which allows of the movement of the aponeurosis, the latter carrying with it the integument.

Nerve-supply.—The Occipitalis is supplied by the posterior auricular branch, and the Frontalis by the temporal branches, of the facial nerve.

Actions.—The Occipitales draw the scalp backwards; the Frontales acting from above raise the eyebrows and the skin over the root of the nose; acting from below they draw the scalp forwards, throwing the integument of the forehead into transverse wrinkles. By bringing alternately into action the Occipitales and Frontales the entire scalp may be moved backwards and forwards. In the ordinary action of the Frontales, the eyebrows are elevated, thus giving to the face the expression of surprise: if the action be exaggerated, the eyebrows are still further raised, and the skin of the forehead thrown into transverse wrinkles, as in the expression of fright or horror.

A thin muscular slip, the *Transversus nuchæ*, is present in about 25 per cent. of cases; it arises from the external occipital protuberance or from the superior nuchal line, either superficial or deep to the Trapezius; it is frequently inserted with the Auricularis posterior, but may join the posterior edge of the Sternocleidomastoideus.

Applied Anatomy.—The scalp consists of five layers, viz. the skin, subcutaneous tissue, Epicranius and its aponeurosis, subaponeurotic connective tissue, and pericranium. But from a surgical standpoint it is better to regard the first three of these as a single layer, since they are all intimately fused together, and when torn off in an accident, or turned down as a flap in a surgical operation, remain firmly connected to each other. In consequence of the dense character of the subcutaneous tissue, the amount of swelling which occurs as the result of inflammation is slight; and the edges of a wound which does not involve the Epicranius or its aponeurosis do not gape. The blood-vessels, also, which lie in this tissue, when wounded, do not contract and retract freely; and therefore the hæmorrhage from scalp wounds is often very considerable, but can always be arrested by pressure—a matter of great importance, as it is often very difficult or impossible to pick up with forceps a wounded vessel in the scalp.

The subaponeurotic connective tissue is, from a surgical point of view, of considerable importance. It is loose and lax, and is easily torn through; and hence, when the scalp is wounded, this is the tissue which is torn when the flap is separated from the parts beneath. The vessels are contained in the flap, and there is little risk of sloughing, unless the vitality of the part has been actually destroyed by the injury. In consequence of the loose nature of the subaponeurotic tissue, any septic inflammation is apt to assume a very diffuse form and spread over the skull, and, unless relieved by timely incisions, may lead to serious complications. Owing to the attachments of the aponeurosis to the zygomatic arch and highest nuchal line, subaponeurotic effusions sag down in these situations, but do not extend beyond to the infratemporal fossa, or into the neck; anteriorly, however, where there is no definite attachment to bone, the effusion will pass down over the nose, and into the eyelids. When making incisions into the scalp, care should be taken to avoid the course of the main arteries.

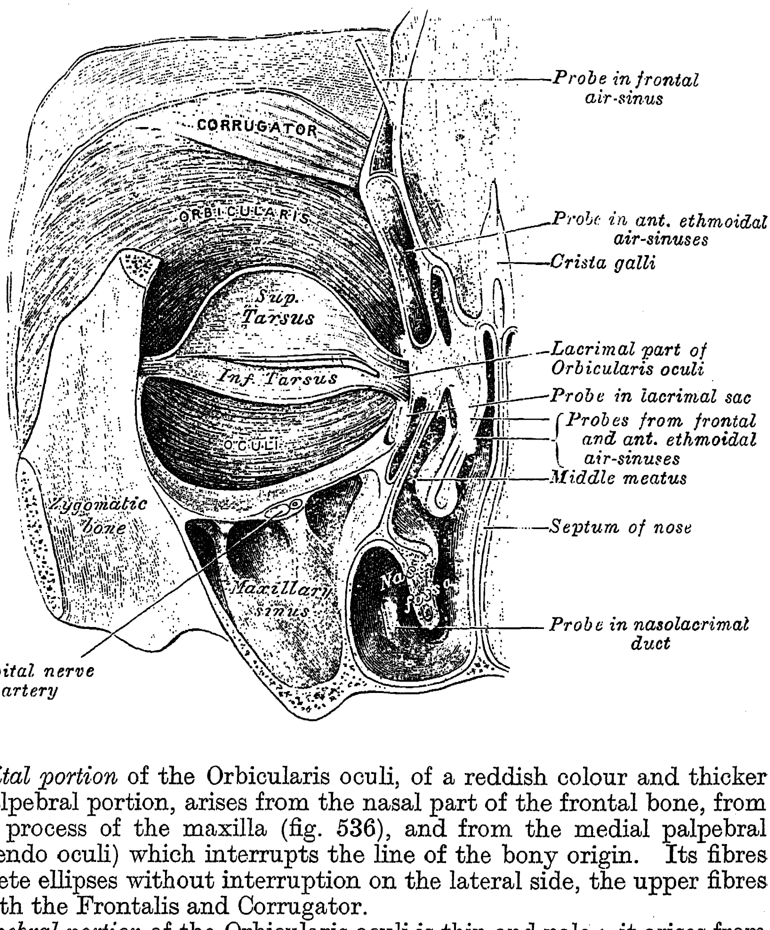
II. The Muscles of the Eyelids

Levator palpebræ superioris. Orbicularis oculi. Corrugator.

The Levator palpebræ superioris is described with the anatomy of the eye.

The **Orbicularis oculi** (figs. 534, 535) is a broad, flat, elliptical muscle which occupies the eyelids or palpebræ, surrounds the circumference of the orbit, spreads over the temporal region, and downwards on the cheek. It consists of three main portions, orbital, palpebral and lacrimal.

Fig. 535.—The left Orbicularis oculi. Posterior aspect.



The *orbital portion* of the Orbicularis oculi, of a reddish colour and thicker than the palpebral portion, arises from the nasal part of the frontal bone, from the frontal process of the maxilla (fig. 536), and from the medial palpebral ligament (tendo oculi) which interrupts the line of the bony origin. Its fibres form complete ellipses without interruption on the lateral side, the upper fibres blending with the Frontalis and Corrugator.

The *palpebral portion* of the Orbicularis oculi is thin and pale ; it arises from the medial palpebral ligament, chiefly from its superficial and partly from its deep surface, but not from its lower margin ; it also arises from the bone immediately above and below the ligament. The muscular fibres sweep across the eyelids in front of the orbital septum, and at the lateral commissure interlace to form the lateral palpebral raphe. A small bundle of very fine fibres lies close to the margin of each eyelid, behind the eyelashes ; it is named the *ciliary bundle* or muscle of Riolan.

The *lacrimal portion* of the Orbicularis oculi (Tensor tarsi) lies behind the lacrimal sac. It arises from the fascia covering the lacrimal sac, from the upper part of the posterior lacrimal crest, and the adjacent part of the lateral surface of the lacrimal bone. Passing lateralwards behind the lacrimal sac the muscle divides into two slips, an upper and a lower ; some of the fibres of these slips are inserted into the superior and inferior tarsi and are closely related to the lacrimal ducts, but most of them are continued across the eyelids

in front of the tarsal plates (*pars tarsalis*) and interlace in the lateral palpebral raphe.

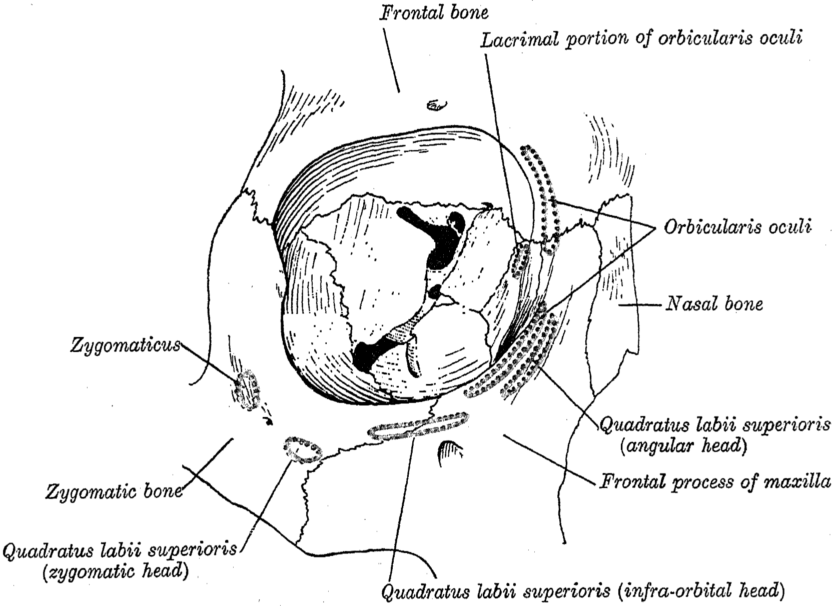
The *medial palpebral ligament* (tendo oculi), about 4 mm. in length and 2 mm. in breadth, is attached to the frontal process of the maxilla in front of the lacrimal groove. Crossing the lacrimal sac, it divides into two parts, upper and lower, each attached to the medial end of the corresponding tarsus. As the ligament crosses the lacrimal sac, an aponeurotic lamina is given off from its posterior surface; this expands over the sac, and is attached to the posterior lacrimal crest.

The *lateral palpebral raphe* is a much weaker structure than the medial palpebral ligament. It is formed by the interlacing of the lateral ends of the palpebral fibres of the Orbicularis oculi, strengthened on its deep surface by the orbital septum. It passes over the orbital margin, and is attached to the bone by connective tissue only (Whitnall).

Nerve-supply.—The Orbicularis oculi is supplied by the temporal and zygomatic branches of the facial nerve.

Actions.—The Orbicularis oculi is the sphincter muscle of the eyelids. The palpebral portion acts involuntarily, closing the lids gently, as in sleep or in blinking; the orbital portion is subject to the will. When the entire muscle is brought into action, the skin of the forehead, temple, and cheek is drawn towards the medial angle of the orbit, and the eyelids are firmly closed. The skin thus drawn upon is thrown into folds, especially radiating from the lateral angle of the eyelids; these folds become permanent in old age, and form the so-called 'crow's feet.' The Levator palpebræ superioris is the direct antagonist of this muscle since it raises the upper eyelid and exposes the front of the bulb of the eye. The lacrimal part of the Orbicularis oculi draws the eyelids and the papillæ lacrimales medialwards, and directs them into the lacus lacrimalis; it also dilates the lacrimal sac.

FIG. 536.—A sketch showing the attachments of the muscles around the base of the orbit.



The **Corrugator** is a small pyramidal muscle, placed at the medial end of the eyebrow, beneath the Frontalis and Orbicularis oculi. It arises from the medial end of the superciliary arch; and its fibres pass lateralwards and slightly upwards, and are inserted into the deep surface of the skin, above the middle of the orbital arch.

Nerve-supply.—The Corrugator is supplied by the temporal branches of the facial nerve.

Actions.—The Corrugator draws the eyebrow medialwards and downwards, producing the vertical wrinkles of the forehead. It is the 'frowning' muscle, and may be regarded as the principal muscle in the expression of suffering.

III. The Muscles of the Nose (fig. 534)

Procerus.	Depressor septi.
Nasalis.	Dilatator naris posterior.

Dilatator naris anterior.

The **Procerus** (Pyramidalis nasi) is a small pyramidal slip arising by tendinous fibres from the fascia covering the lower part of the nasal bone and upper part of the lateral nasal cartilage; it is inserted into the skin over the lower part of the forehead between the two eyebrows, its fibres decussating with those of the Frontalis.

Nerve-supply.—The Procerus is supplied by the buccal branches of the facial nerve.

Actions.—The Procerus draws down the medial angle of the eyebrow and produces the transverse wrinkles over the bridge of the nose.

The **Nasalis** (Compressor naris) consists of two parts, transverse and alar. The *transverse part* arises from the maxilla, above and lateral to the incisive fossa; its fibres proceed upwards and medialwards, expanding into a thin aponeurosis which is continuous on the bridge of the nose with that of the muscle of the opposite side, and with the aponeurosis of the Procerus. The *alar part* is attached by one end to the greater alar cartilage, and by the other to the integument at the apex of the nose.

Nerve-supply.—The Nasalis is supplied by the buccal branches of the facial nerve.

Actions.—The Nasalis depresses the cartilaginous part of the nose, and draws the ala towards the septum.

The **Depressor septi** arises from the incisive fossa of the maxilla; its fibres ascend to be inserted into the septum and back part of the ala of the nose. It lies between the mucous membrane and muscular structure of the lip.

Nerve-supply.—The Depressor septi is supplied by the buccal branches of the facial nerve.

Actions.—The Depressor septi is a direct antagonist of the other muscles of the nose, drawing the ala of the nose downwards and thereby constricting the aperture of the naris.

The **Dilatator naris posterior** is placed partly beneath the Quadratus labii superioris. It arises from the margin of the nasal notch of the maxilla, and from the lesser alar cartilages, and is inserted into the skin near the margin of the nostril.

The **Dilatator naris anterior** is a delicate fasciculus, passing from the greater alar cartilage to the integument near the margin of the nostril; it is situated in front of the preceding.

Nerve-supply.—The Dilatatores naris, posterior et anterior, are supplied by the buccal branches of the facial nerve.

Actions.—The Dilatatores enlarge the apertures of the nares. Their action in ordinary breathing is to resist the tendency of the nares to close from atmospheric pressure, but in difficult breathing, as well as in some emotions, such as anger, they contract strongly.

IV. The Muscles of the Mouth (fig. 534)

Quadratus labii superioris.	Quadratus labii inferioris.
Caninus.	Triangularis.
Zygomaticus.	Buccinator.
Mentalis.	Orbicularis oris.

Risorius.

The **Quadratus labii superioris** is a broad sheet, the origin of which extends from the side of the nose to the zygomatic bone. Its medial fibres

form the *angular head*, which arises by a pointed extremity from the upper part of the frontal process of the maxilla, and passing obliquely downwards and lateralwards divides into two slips. One of these is inserted into the greater alar cartilage and skin of the nose; the other is prolonged into the lateral part of the upper lip, blending with the infra-orbital head and with the Orbicularis oris. The intermediate portion or *infra-orbital head* arises from the lower margin of the orbit immediately above the infra-orbital foramen, some of its fibres arising from the maxilla, others from the zygomatic bone. Its fibres converge, to be inserted into the muscular substance of the upper lip between the angular head and the Caninus. The lateral fibres form the *zygomatic head*, and are separated from the rest of the muscle by a narrow interval; they arise from the malar surface of the zygomatic bone immediately behind the zygomaticomaxillary suture and pass downwards and medialwards to the upper lip.

Nerve-supply.—The Quadratus labii superioris is supplied by the buccal branches of the facial nerve.

Actions.—The Quadratus labii superioris raises the upper lip and at the same time everts it. Its angular head also acts as a dilator of the naris; the infra-orbital and zygomatic heads assist in forming the nasolabial furrow, which passes from the side of the nose to the upper lip and gives to the face an expression of sadness. When the whole muscle is in action it gives to the countenance the expression of contempt and disdain.

The **Caninus** (Levator anguli oris) arises from the canine fossa, immediately below the infra-orbital foramen; its fibres are inserted into the angle of the mouth, intermingling with those of the Zygomaticus, Triangularis, and Orbicularis oris.

Nerve-supply.—The Caninus is supplied by the buccal branches of the facial nerve.

Actions.—The Caninus raises the angle of the mouth and assists in producing the nasolabial furrow.

The **Zygomaticus** arises from the zygomatic bone, in front of the zygomaticotemporal suture, and descending obliquely with a medial inclination, is inserted into the angle of the mouth, where it blends with the fibres of the Caninus, Orbicularis oris, and Triangularis.

Nerve-supply.—The Zygomaticus is supplied by the buccal branches of the facial nerve.

Actions.—The Zygomaticus draws the angle of the mouth upwards and lateralwards as in laughing.

The **Mentalis** (Levator menti) is a conical fasciculus, situated at the side of the frenulum of the lower lip. It arises from the incisive fossa of the mandible and descends to be inserted into the integument of the chin.

Nerve-supply.—The Mentalis is supplied by the mandibular branch of the facial nerve.

Actions.—The Mentalis raises and protrudes the lower lip, and at the same time wrinkles the skin of the chin, expressing doubt or disdain.

The **Quadratus labii inferioris** is a quadrilateral muscle. It arises from the oblique line of the mandible, between the symphysis and the mental foramen, and passes upwards and medialwards, to be inserted into the integument of the lower lip, its fibres blending with the Orbicularis oris, and with those of its fellow of the opposite side. At its origin it is continuous with the fibres of the Platysma. Much yellow fat is intermingled with the fibres of this muscle.

Nerve-supply.—The Quadratus labii inferioris is supplied by the mandibular branch of the facial nerve.

Actions.—The Quadratus labii inferioris draws the lower lip downwards and a little lateralwards, as in the expression of irony.

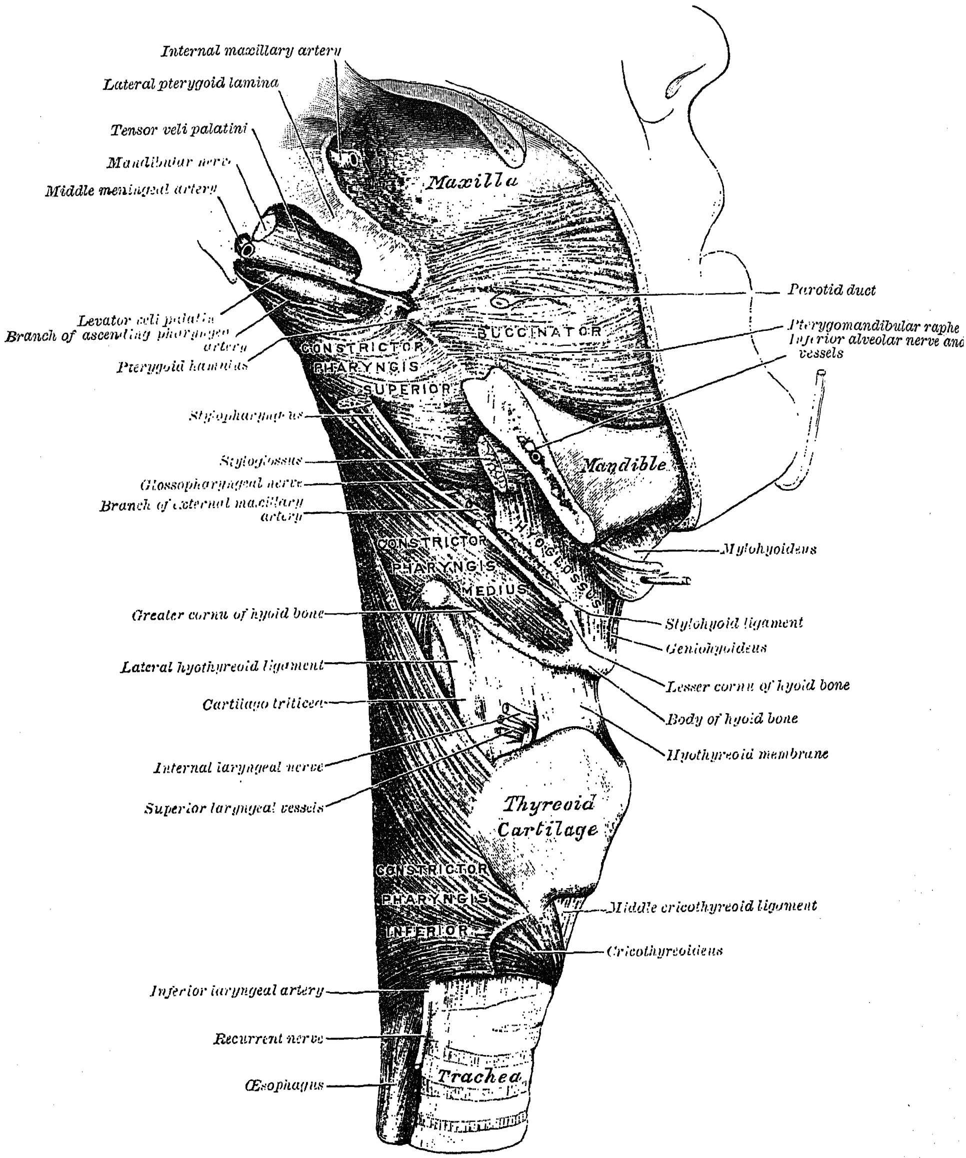
The **Triangularis** (Depressor anguli oris) arises from the oblique line of the mandible below and lateral to the Quadratus labii inferioris; its fibres converge and are inserted by a narrow fasciculus into the angle of the mouth. At its origin it is continuous with the Platysma, and at its insertion with the Orbicularis oris and Risorius; some of its fibres are directly continuous with those of the Caninus, and others are occasionally found crossing from the muscle of one side to that of the other; these latter fibres constitute the *Transversus menti*.

Nerve-supply.—The Triangularis is supplied by the mandibular branch of the facial nerve.

Actions.—The Triangularis draws the angle of the mouth downwards and lateralwards.

The **Buccinator** (fig. 537) is a thin quadrilateral muscle, occupying the interval between the maxilla and the mandible, at the side of the face. It arises

FIG. 537.—The Buccinator and the muscles of the pharynx.



from the outer surfaces of the alveolar processes of the maxilla and mandible, opposite to the three molar teeth; and behind, from the anterior border of the pterygomandibular raphe which separates the muscle from the Constrictor pharyngis superior. The fibres converge towards the angle of the mouth, where the central fibres intersect each other, those from below being continuous with the upper segment of the Orbicularis oris, and those from above with the lower segment; the highest and lowest fibres are continued forward into the corresponding lip without decussation.

Relations.—The Buccinator is covered by the buccopharyngeal fascia, and is in relation by its *superficial surface*, behind, with a large mass of fat, which separates it from the ramus of the mandible, the Masseter, and a small portion of the Temporalis; this fat has been named the *suctorial pad*, because it is supposed to assist in the act of sucking. In front the superficial surface of the Buccinator is in relation with the Zygomaticus, Risorius, Caninus, Triangularis, and the parotid duct which pierces it opposite the second molar tooth of the maxilla; the external maxillary artery and anterior facial vein cross it from below upwards; it is also crossed by branches of the facial and buccinator nerves. The *deep surface* is in relation with the buccal glands and mucous membrane of the mouth.

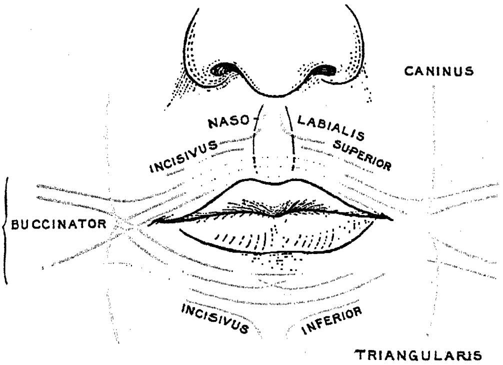
Nerve-supply.—The Buccinator is supplied by the buccal branches of the facial nerve.

Actions.—The Buccinator muscles compress the cheeks against the teeth, so that during the process of mastication the food is kept under the immediate pressure of the teeth. When the cheeks have been previously distended with air, the Buccinators expel it between the lips, as in blowing a trumpet; hence the name (*buccina*, a trumpet).

The *pterygomandibular raphe* is a tendinous band of the buccopharyngeal fascia, attached by one extremity to the hamulus of the medial pterygoid lamina, and by the other to the posterior end of the mylohyoid line of the mandible. *Medially* it is covered by the mucous membrane of the mouth. *Laterally* it is separated from the ramus of the mandible by a quantity of adipose tissue. *Posteriorly* it gives attachment to the Constrictor pharyngis superior, and *anteriorly* to a part of the Buccinator (fig. 537).

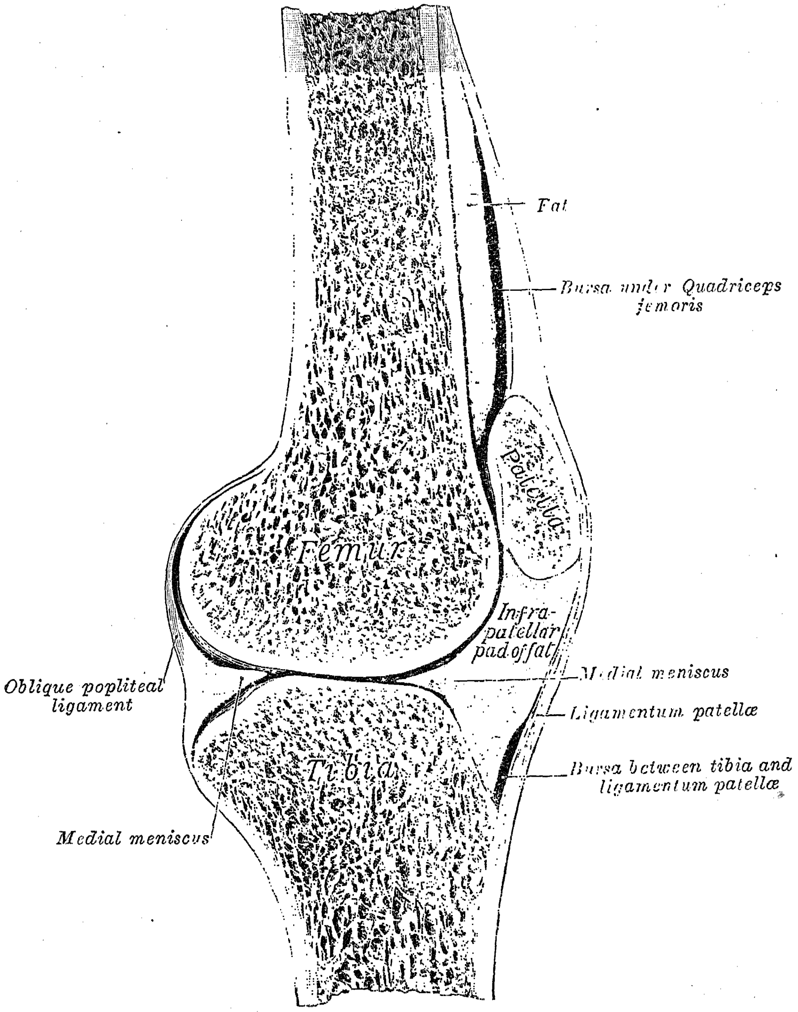
The **Orbicularis oris** (figs. 534, 538) is not a simple sphincter muscle like the Orbicularis oculi; it consists of numerous strata of muscular fibres surrounding the orifice of the mouth but having different directions. It consists partly of fibres derived from the other facial muscles which are inserted into the lips, and partly of fibres proper to the lips. Of the former, a considerable number are derived from the Buccinator, and form the deeper stratum of the Orbicularis. Some of the Buccinator fibres—namely, those near the middle of the muscle—decussate at the angle of the mouth; the uppermost and lowermost fibres pass across the lips from side to side without decussation. Superficial to this is a second stratum, formed on either side by the Caninus and Triangularis, which cross each other at the angle of the mouth; the fibres from the Caninus pass to the lower lip, and those from the Triangularis to the upper lip, along which they run, to be inserted into the skin near the median line. In addition to these there are fibres from the Quadratus labii superioris, the Zygomaticus, and the Quadratus labii inferioris; these intermingle with the transverse fibres described above, and have principally an oblique direction. The proper fibres of the lips are oblique, and pass from the deep surface of the skin to the mucous membrane, through the thickness of the lip. Finally there are fibres by which the muscle is connected with the maxillæ and the septum of the nose above and with the mandible below. In the upper lip these consist of two bands, lateral and medial, on either side of the middle line; the lateral band (*m. incisivus labii superioris*) arises from the alveolar border of the maxilla, opposite the lateral incisor tooth, and arching lateralwards is continuous with the other muscles at the angle of the mouth; the medial band (*m. nasolabialis*) connects the upper lip to the back of the septum of the nose. The interval between the two medial bands corresponds with the depression, called the *philtrum*, seen on the lip beneath the septum of the nose. The additional fibres for the lower lip constitute a slip (*m. incisivus*

Fig. 538.—A scheme showing the arrangement of the fibres of the Orbicularis oris.



the passage of the limb from the flexed to the extended position a gliding movement is superposed on the rolling, so that the axis, which at the commencement is represented by a line through the medial and lateral condyles of the femur, gradually shifts forwards. In this part of the movement, the posterior two-thirds of the femoral condyles are involved, and as these have similar curvatures and are parallel to one another, they move equally. The lateral condyle of the femur is brought almost to rest by the tightening of the anterior cruciate ligament; it moves, however, slightly forwards and medialwards, pushing before it the

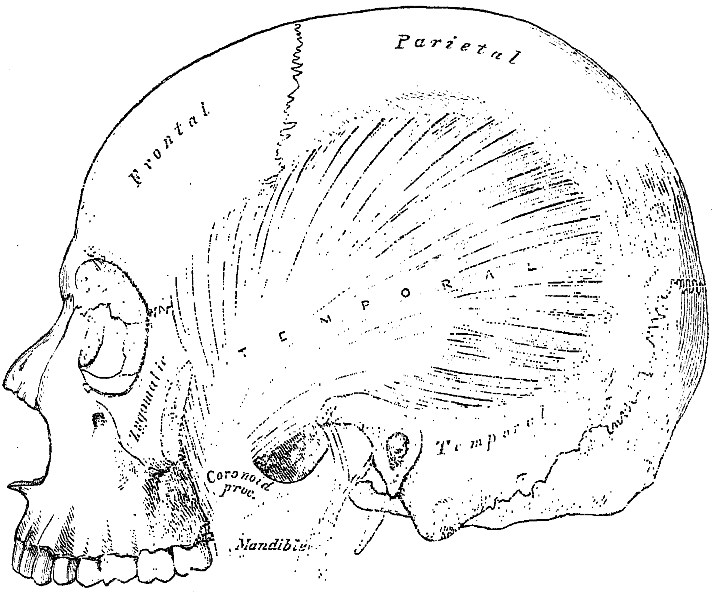
FIG. 522.—A sagittal section through the right knee-joint. Lateral aspect.



anterior part of the lateral meniscus. The tibial surface on the medial condyle is prolonged farther forwards than that on the lateral, and this prolongation is directed lateralwards. When, therefore, the movement of the lateral condyle is checked by the anterior cruciate ligament, continued muscular action causes the medial condyle, dragging with it the meniscus, to travel backwards and medialwards, thus producing an internal rotation of the thigh on the leg. When the position of full extension is reached the lateral part of the groove on the lateral condyle is pressed against the anterior part of the corresponding meniscus, while the medial part of the groove rests on the articular margin in front of the lateral process of the tibial intercondyloid eminence. Into the groove on the medial condyle is fitted the anterior part of the medial meniscus, while the anterior cruciate ligament and the articular margin in front of the medial process of the tibial

fascia. Its fibres converge as they descend, and end in a tendon which passes deep to the zygomatic arch and is inserted into the medial surface, apex, and anterior border of the coronoid process, and the anterior border of the ramus of the mandible nearly as far forwards as the last molar tooth.

FIG. 539.—The left Temporalis. The zygomatic arch and the Masseter have been removed.



Relations.—*Superficial* to the muscle are the skin, the Auriculares anterior et superior, the temporal fascia, the superficial temporal vessels, the auriculotemporal nerve, the temporal branches of the facial nerve, the zygomaticotemporal nerve, the galea aponeurotica, the zygomatic arch, and the Masseter. The *deep surface* is in relation with the temporal fossa, the Pterygoideus externus and part of the Buccinator, the internal maxillary artery and its deep temporal branches, the deep temporal nerves, and the buccinator vessels and nerve. *Behind* the tendon of the muscle are the masseteric vessels and nerve. The *anterior border* is separated from the zygomatic bone by a mass of fat.

Nerve-supply.—The Temporalis is supplied by the deep temporal branches of the anterior trunk of the mandibular nerve.

Actions.—The Temporalis pulls the mandible towards and against the maxillæ; its posterior fibres draw the condyle backwards.

The **Pterygoideus externus** (fig. 540) is a short, thick muscle, somewhat conical in form. It arises by two heads: an *upper* from the infratemporal surface and infratemporal crest of the great wing of the sphenoidal bone; and a *lower* from the lateral surface of the lateral pterygoid lamina. Its fibres pass horizontally backwards and lateralwards, to be inserted into a depression (pterygoid fovea) on the front of the neck of the condyle of the mandible, and into the articular capsule and disc of the mandibular articulation.

Relations.—Its *superficial surface* is in relation with the ramus of the mandible, the internal maxillary artery, which crosses it,* the tendon of the Temporalis, and the Masseter. Its *deep surface* rests against the upper part of the Pterygoideus internus, the sphenomandibular ligament, the middle meningeal artery, and the mandibular nerve; its *upper border* is in relation with the temporal and masseteric branches of the mandibular nerve; its *lower border* with the lingual and inferior alveolar nerves. The buccinator nerve and the internal maxillary artery pass between the heads of the muscle.

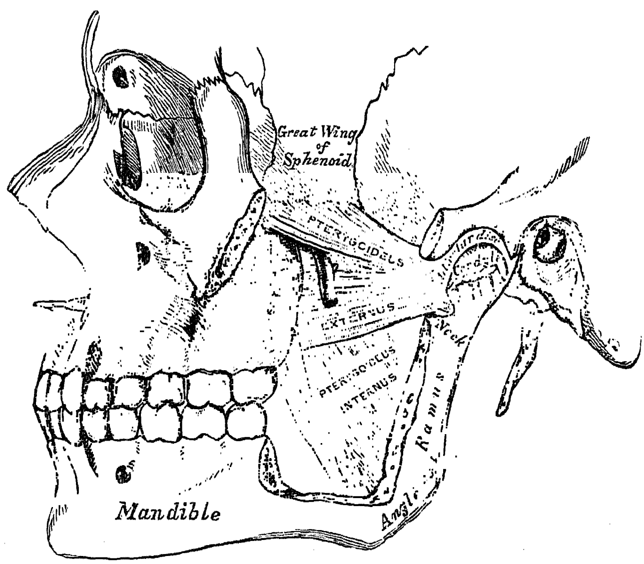
Nerve-supply.—The Pterygoideus externus is supplied by a branch from the anterior trunk of the mandibular nerve.

* In many cases the artery lies deep to the muscle.

Actions.—The Pterygoideus externus assists in opening the mouth, by pulling forward the condyle of the mandible and the articular disc, while the body of the mandible is being depressed by the suprahyoid muscles. Acting with the Pterygoideus internus it protrudes the mandible so that the lower incisors are projected in front of the upper.

The **Pterygoideus internus** (fig. 540), a thick, quadrilateral muscle, arises from the medial surface of the lateral pterygoid lamina and the grooved surface of the pyramidal process of the palatine bone; it has a second slip

FIG. 540.—The left Pterygoidei. The zygomatic arch and a portion of the ramus of the mandible have been removed.



of origin from the lateral surfaces of the pyramidal process of the palatine bone and tuberosity of the maxilla. Its fibres pass downwards, lateralwards, and backwards, and are inserted, by a strong tendinous lamina, into the lower and back part of the medial surfaces of the ramus and angle of the mandible, as high as the mandibular foramen.

Relations.—The *lateral surface* of the muscle is in relation with the ramus of the mandible, from which it is separated, at its upper part, by the Pterygoideus externus, the sphenomandibular ligament, the internal maxillary artery, the inferior alveolar vessels and nerve, the lingual nerve, and a process of the parotid gland. The *medial surface* is in relation with the Tensor veli palatini, and is separated from the Constrictor pharyngis superior by some areolar tissue.

Nerve-supply.—The Pterygoideus internus is supplied by a branch from the mandibular nerve.

Actions.—The Pterygoideus internus assists in approximating the mandible to the maxillæ. Acting with the Pterygoideus externus it protrudes the mandible. When the two Pterygoidei of one side are in action, the corresponding side of the mandible is drawn forwards, while the opposite condyle remains comparatively fixed; by an alternating action of the muscles of the two sides, the side-to-side movements, such as take place during trituration of the food, are effected.

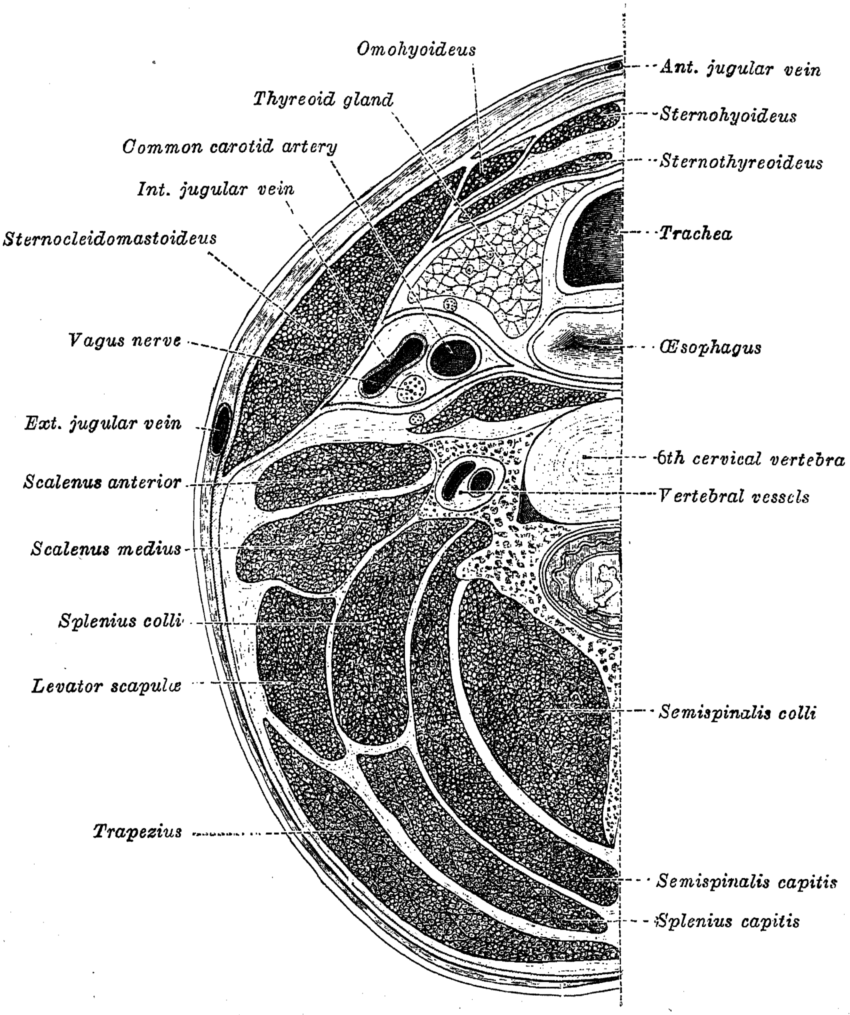
THE FASCIÆ AND MUSCLES OF THE ANTEROLATERAL REGION OF THE NECK

The anterolateral muscles of the neck may be arranged into the following groups :

I. Superficial and lateral cervical.
II. Supra- and infra-hyoid.
III. Anterior vertebral.
IV. Lateral vertebral.

The **superficial fascia** of the neck is a thin lamina investing the Platysma, and is hardly demonstrable as a separate membrane.

FIG. 541.—A transverse section through the left half of the neck at about the level of the sixth cervical vertebra, showing the arrangement of the fascia colli.



The **fascia colli** (deep cervical fascia) (fig. 541) lies under cover of the Platysma, and invests the muscles of the neck; it also forms sheaths for the carotid vessels, and for the structures situated in front of the vertebral column.

The investing portion of the fascia is attached behind to the ligamentum nuchæ and to the spinous process of the seventh cervical vertebra. It forms a thin investment for the Trapezius, and from the anterior border of this muscle is continued forwards, as a rather loose areolar layer covering the posterior triangle of the neck, to the posterior border of the Sternocleidomastoideus, where it begins to assume the appearance of a fascial membrane. Along the hinder edge of the Sternocleidomastoideus it divides to enclose the muscle, and at the anterior margin again forms a single lamella, which covers the anterior triangle of the neck, and reaches forwards to the middle line, where it is continuous with the corresponding part from the opposite side of the neck. In the middle line of the neck it is fixed to the symphysis menti and the body of the hyoid bone.

Above, the fascia is attached to the superior nuchal line of the occipital bone, to the mastoid process of the temporal bone, and to the whole length of the inferior border of the body of the mandible. Opposite the angle of the mandible it is very strong, and binds the anterior edge of the Sternocleidomastoideus firmly to that bone. Between the mandible and the mastoid process it ensheathes the parotid gland—the layer which covers the gland extends upwards under the name of the *parotideomasseteric fascia* and is fixed to the zygomatic arch. From the part which passes under the parotid gland a strong band ascends to the styloid process, forming the *stylomandibular ligament* (p. 356). Two other bands may be defined: the *sphenomandibular* (p. 356) and the *pterygospinous ligaments*. The *pterygospinous ligament* stretches from the upper part of the posterior border of the lateral pterygoid lamina to the spinous process of the sphenoidal bone. It occasionally ossifies, and when this occurs a foramen is formed between it and the base of the skull, and transmits the branches of the mandibular nerve to the muscles of mastication.

Below, the fascia is attached to the acromion, the clavicle, and the manubrium sterni. Some little distance above the last, it splits into a superficial and a deep layer. The former is attached to the anterior border of the manubrium, the latter to its posterior border and to the interclavicular ligament. Between these two layers is a slit-like interval, the *suprasternal space*, or *space of Burns*; it contains a small quantity of areolar tissue, the lower portions of the anterior jugular veins and their transverse connecting branch, the sternal heads of the Sternocleidomastoidei, and sometimes a lymph-gland.

From the fascia lining the deep surface of the Sternocleidomastoideus four processes pass off. (1) One envelops the tendon of the Omohyoideus, and binds it down to the sternum and first costal cartilage. (2) The *carotid sheath* encloses the carotid artery, internal jugular vein, and vagus nerve. (3) The *prevertebral fascia* extends medialwards behind the carotid vessels, where it assists in forming their sheath, and passes in front of the prevertebral muscles. It forms the posterior wall of a fibrous compartment which contains the larynx and trachea, the thyreoid gland, and the pharynx and œsophagus. The prevertebral fascia is fixed above to the base of the skull, and below is continued into the thorax in front of the Longus colli muscles. Parallel to the carotid sheath and along its medial aspect the prevertebral fascia gives off a thin lamina, the *buccopharyngeal fascia*, which closely invests the Constrictor muscles of the pharynx, and is continued forward from the Constrictor pharyngis superior on to the Buccinator. It is attached to the prevertebral layer by loose connective tissue only, and thus an easily distended space, the *retropharyngeal space*, is found between them. This space is limited above by the base of the skull; below it extends behind the œsophagus into the posterior mediastinal cavity of the thorax. The prevertebral fascia is prolonged downwards and lateralwards behind the carotid vessels and in front of the Scaleni, and forms a sheath for the brachial nerves and subclavian vessels in the posterior triangle of the neck; it is continued under the clavicle as the axillary sheath and is attached to the deep surface of the coracoclavicular fascia. Immediately above and behind the clavicle an areolar space exists between the investing layer and the sheath of the subclavian vessels, and in this space are found the lower part of the external jugular vein, the supraclavicular nerves, the transverse scapular and transverse cervical vessels, and the inferior belly of the Omohyoideus muscle. This space is limited below by the fusion of the coracoclavicular fascia with the anterior wall of the axillary sheath. (4) The

pretracheal fascia extends medialwards in front of the carotid vessels, and assists in forming the carotid sheath. It is continued behind the infrahyoid muscles, and, after enveloping the thyreoid gland, is prolonged in front of the trachea to meet the corresponding layer of the opposite side. Above, it is fixed to the hyoid bone; below, it is carried downwards in front of the trachea and large vessels at the root of the neck, and ultimately blends with the fibrous pericardium. This layer is fused on either side with the prevertebral fascia, and with it completes the compartment containing the larynx and trachea, the thyreoid gland, and the pharynx and œsophagus.*

Applied Anatomy.—The fascia colli (deep cervical fascia) is of considerable importance from a surgical point of view. The investing layer opposes the extension of abscesses towards the surface, and pus forming beneath it has a tendency to extend lateralwards. If the pus be contained in the anterior triangle, it may find its way into the anterior mediastinal cavity, in front of the pretracheal layer of fascia; but owing to the thinness of the fascia in this situation it more frequently finds its way to the surface and points above the sternum. Pus forming under cover of the pretracheal layer would in all probability find its way into the posterior mediastinal cavity. Pus forming behind the prevertebral layer, in cases, for instance, of caries of the bodies of the cervical vertebræ, may extend towards the lateral part of the neck and point in the posterior triangle, or may perforate this layer of fascia and the buccopharyngeal fascia and point into the pharynx (retropharyngeal abscess).

In cases of cut throat, when the wound involves only the investing layer the injury is usually trivial, the special danger being injury to the external jugular vein, and the special complication, diffuse cellulitis. But where the second of the two layers is opened up, important structures may be injured, and serious results follow.

The sternal head of origin of the Sternocleidomastoideus is contained in the suprasternal space, so that this space is opened in division of this tendon. The lower part of the anterior jugular vein is also contained in the same space.

I. The Superficial and Lateral Cervical Muscles

Platysma. Trapezius. Sternocleidomastoideus.

The **Platysma** (fig. 534) is a broad sheet arising from the fascia covering the upper parts of the Pectoralis major and Deltoideus; its fibres cross the clavicle, and proceed obliquely upwards and medialwards along the side of the neck. The anterior fibres interlace, below and behind the symphysis menti, with the fibres of the muscle of the opposite side; the posterior fibres cross the mandible, some being inserted into the bone below the oblique line, others into the skin and subcutaneous tissue of the lower part of the face, many of these fibres blending with the muscles about the angle and lower part of the mouth. Sometimes fibres can be traced to the Zygomaticus, or to the margin of the Orbicularis oculi. Beneath the Platysma, the external jugular vein descends from the angle of the mandible to the middle of the clavicle.

Nerve-supply.—The Platysma is supplied by the cervical branch of the facial nerve.

Actions.—When the entire Platysma is in action it produces a wrinkling of the surface of the skin of the neck in an oblique direction, and tends to diminish the concavity between the jaw and the side of the neck. Its anterior portion, the thickest part of the muscle, may assist in depressing the mandible; it also serves to draw down the lower lip and angle of the mouth in the expression of horror or surprise.

The **Trapezius** is described on p. 493.

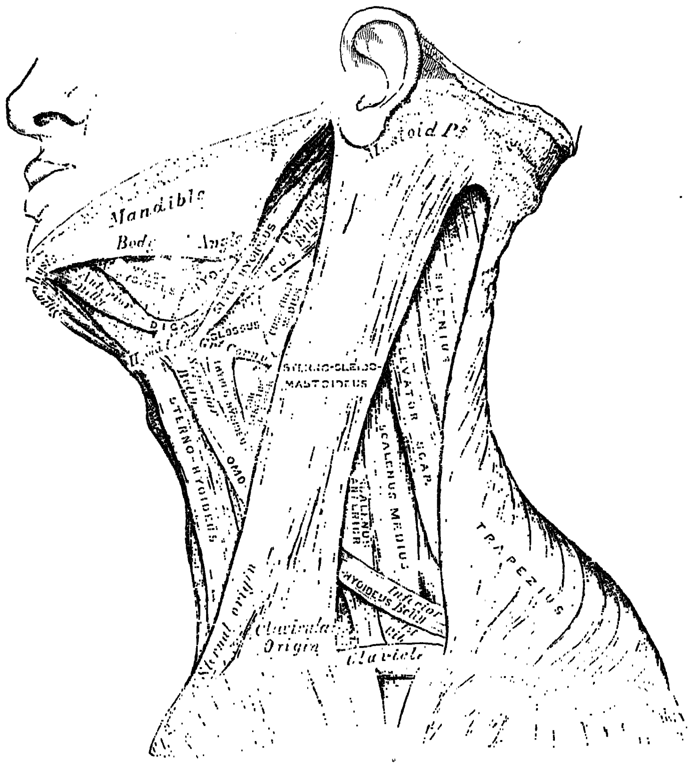
The **Sternocleidomastoideus** (fig. 542) passes obliquely across the side of the neck. It is thick and narrow at its central part, but broader and thinner at either end. It arises by two heads. The *medial or sternal head* is a rounded tendinous fasciculus, which arises from the upper part of the anterior surface of the manubrium sterni, and is directed upwards, lateralwards, and backwards. The *lateral or clavicular head*, composed of fleshy and aponeurotic fibres, arises from the superior border and anterior surface of the medial one-third of the

* F. G. Parsons (*Journal of Anatomy and Physiology*, vol. xliv.) regards the carotid sheath and the fascial planes in the neck as structures which are artificially produced by dissection.

clavicle, and is directed almost vertically upwards. The two heads are separated from one another at their origins by a triangular interval, but gradually blend, below the middle of the neck, into a thick, rounded belly. The muscle is inserted by a strong tendon into the lateral surface of the mastoid process, from its apex to its superior border, and by a thin aponeurosis into the lateral half of the superior nuchal line of the occipital bone.

The Sternocleidomastoideus varies much in its extent of origin from the clavicle: in some cases the clavicular may be as narrow as the sternal head; in others, as much as 7·5 cm. in breadth. When the clavicular origin is broad, it is occasionally subdivided into several slips. More rarely, the adjoining margins of the Sternocleidomastoideus and Trapezius are in contact.

FIG. 542.—The muscles of the neck. Left lateral aspect.



This muscle divides the quadrilateral area of the side of the neck into two triangles, an anterior and a posterior. The boundaries of the *anterior triangle* are, in front, the median line of the neck; above, the lower border of the body of the mandible, and a line continuing this from the angle of the mandible to the Sternocleidomastoideus; behind, the anterior border of the Sternocleidomastoideus. The apex of the triangle is at the upper border of the sternum. The boundaries of the *posterior triangle* are, in front, the posterior border of the Sternocleidomastoideus; below, the middle one-third of the clavicle; behind, the anterior margin of the Trapezius. The apex corresponds with the meeting of the Sternocleidomastoideus and Trapezius on the occipital bone.

Relations.—*Superficial* to the muscle are the integument and Platysma; it is separated from the Platysma by the external jugular vein, the great auricular and cervical cutaneous nerves, and the investing layer of the deep cervical fascia. The *deep surface* is in relation with the sternoclavicular articulation, the process of the deep cervical fascia which binds the inferior belly of the Omohyoideus to the sternum and clavicle, the Sternohyoideus, Sternothyreoideus, Omohyoideus, posterior belly of the Digastricus, Levator scapulæ, Splenius and Scaleni muscles, the common carotid artery, the internal and

anterior jugular veins, the origins of the internal and external carotid arteries, the occipital, subclavian, transverse cervical, and transverse scapular arteries and veins, the phrenic, vagus, hypoglossal, descendens and communicantes hypoglossi nerves, the accessory nerve which pierces its upper third, the cervical plexus, the upper part of the brachial plexus, parts of the thyreoid and parotid glands and their vessels, and the deep cervical lymph-glands.

Nerve-supply.—The Sternocleidomastoideus is supplied by the accessory nerve, which traverses it, and by branches from the anterior divisions of the second and third cervical nerves.

Actions.—When one Sternocleidomastoideus acts, it draws the head towards the shoulder of the same side; it also rotates the head so as to carry the face towards the opposite side. Acting together from their sternoclavicular attachments the two muscles will flex the cervical part of the vertebral column; if the head be fixed they will assist in elevating the thorax in forced inspiration.

Applied Anatomy.—The deformity known as *wry-neck* is due to a contracted condition of the Sternocleidomastoideus. It may be temporary, as the result of direct irritation of the muscle or of the nerves supplying it. It may, however, be permanent, and is then most often due to injury to the muscle during birth, rupture of the fibres and subsequent cicatricial contraction taking place. In these cases, division of the muscle is often necessary to effect a cure, and this may be done either subcutaneously or through an open wound. The open method is, however, much to be preferred, as being the more effectual and the less dangerous, if precautions are taken to keep the wound aseptic. The tendons of origin are freely exposed by a horizontal incision across the root of the neck and carefully divided; any tense bands of fascia which exist should also be divided. The wound is now sutured and dressed, and the head fixed in as straight a position as possible.

There is also a condition coming on in adult life (spasmodic torticollis), which is a very distressing form of functional nervous disease. It begins with tonic or clonic spasm of one Sternocleidomastoideus, which is soon followed by spasm of the Trapezius, particularly its clavicular portion. The Splenius of the opposite side, the Scaleni, Semispinales capitis, and Longissimi capitis may all become involved in turn, with secondary contracture of the fascia colli. Operation in these cases often fails to give satisfactory results. Tenotomy of the affected muscles or section of the nerves supplying them may afford temporary relief, but the spasm often returns when the cut nerves or muscles rejoin.

II. The Supra- and Infra-hyoid Muscles (figs. 542, 543)

The suprahyoid muscles are:

Digastricus.	Mylohyoideus.
Stylohyoideus.	Geniohyoideus.

The **Digastricus** consists of two fleshy bellies united by an intermediate rounded tendon. It lies below the body of the mandible, and extends, in a curved form, from the mastoid process to the chin. The *posterior belly*, longer than the anterior, arises from the mastoid notch (digastric fossa) of the temporal bone and passes downwards and forwards. The *anterior belly* arises from a depression on the inner side of the lower border of the body of the mandible close to the middle line, and passes downwards and backwards. The two bellies end in an intermediate tendon which perforates the Stylohyoideus muscle, and is held in connexion with the side of the body and the greater cornu of the hyoid bone by a fibrous loop, which is sometimes lined by a mucous sheath. An aponeurotic layer is given off from the tendon of the Digastricus on either side of the neck, to be attached to the body and greater cornu of the hyoid bone; this is termed the *suprahyoid aponeurosis*.

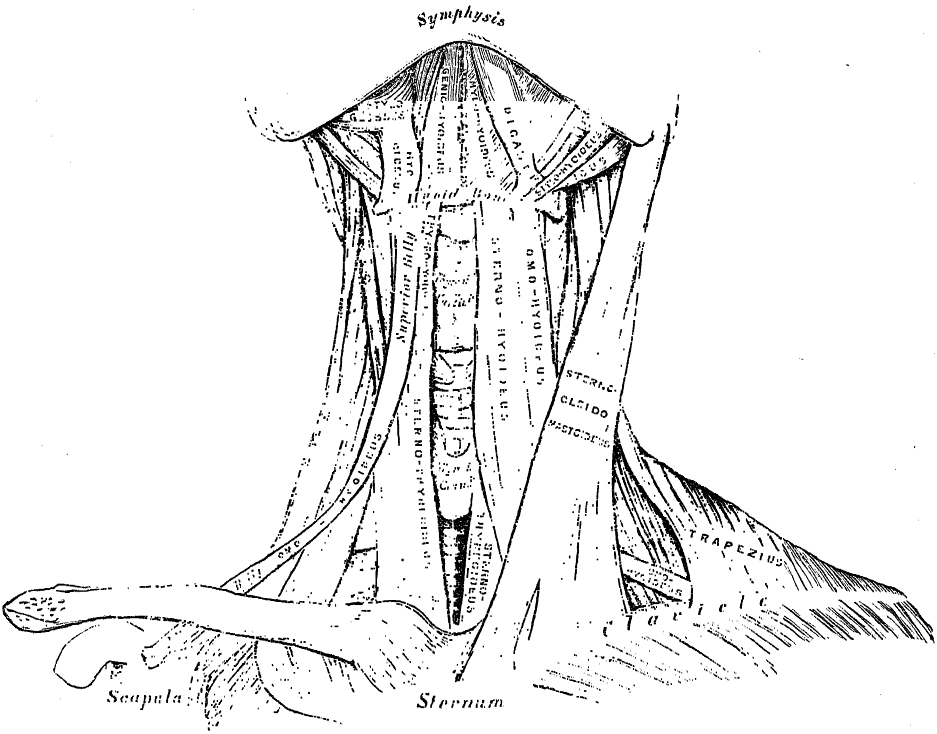
Relations.—Its *superficial surface* is in relation with the Platysma, Sternocleidomastoideus, part of the Splenius, Longissimus capitis, mastoid process, Stylohyoideus, and the parotid gland. The *deep surface* of the anterior belly lies on the Mylohyoideus; that of the posterior belly on the Styloglossus, Stylopharyngeus, and Hyoglossus, the external carotid artery and its occipital, lingual, external maxillary, and ascending pharyngeal branches, the internal carotid artery, internal jugular vein, and hypoglossal nerve.

Nerve-supply.—The anterior belly of the Digastricus is supplied by the mylohyoid branch of the inferior alveolar nerve; the posterior belly by the facial nerve.

Actions.—When the anterior belly of the Digastricus takes its fixed point below, it depresses the front of the mandible. If both bellies are in action from above, they elevate the hyoid bone, the anterior belly tending to draw it upwards and forwards, the posterior upwards and backwards.

The Digastricus divides the upper part of the anterior triangle of the neck into three triangles: (1) the *submaxillary triangle*, bounded above by the lower border of the mandible and a line prolonging this from the angle of the mandible to the Sternocleidomastoideus, below by the posterior belly of the Digastricus and the Stylohyoideus, in front by the anterior belly of the Digastricus; (2) the *carotid*

FIG. 543.—The muscles of the neck. Anterior aspect.



triangle, bounded above by the posterior belly of the Digastricus and Stylohyoideus, behind by the Sternocleidomastoideus, below by the Omohyoideus; (3) the *suprahyoid or submental triangle*, bounded on either side by the anterior belly of the Digastricus, and inferiorly by the body of the hyoid bone.

The **Stylohyoideus** is a slender muscle, lying in front of, and above, the posterior belly of the Digastricus. It arises from the posterior and lateral surfaces of the styloid process, near the base; and, passing downwards and forwards, is inserted into the body of the hyoid bone, at its junction with the greater cornu, and just above the Omohyoideus. It is perforated, near its insertion, by the tendon of the Digastricus.

Nerve-supply.—The Stylohyoideus is supplied by the facial nerve.

Action.—The Stylohyoideus draws the hyoid bone upwards and backwards.

The *stylohyoid ligament.*—In connexion with the Stylohyoideus muscle a ligamentous band, the *stylohyoid ligament*, may be described. It is a fibrous cord, which is attached to the tip of the styloid process of the temporal bone and to the lesser cornu of the hyoid bone. It frequently contains a little cartilage in its centre, is often partially ossified, and in many animals forms a distinct bone, the *epihyal*.

The **Mylohyoideus**, flat and triangular, is situated immediately above the anterior belly of the Digastricus, and forms, with its fellow of the opposite side, a muscular floor for the cavity of the mouth. It arises from the whole length of the mylohyoid line of the mandible. The posterior fibres pass medialwards and slightly downwards, to be inserted into the front of the body of the hyoid bone near its lower border. The middle and anterior fibres are inserted into a median fibrous raphe extending from the mandibular symphysis to the hyoid bone, where they join at an angle with the fibres of the opposite muscle. This median raphe is sometimes wanting; the fibres of the two muscles are then continuous.

Relations.—Its *superficial or inferior surface* is in relation with the Platysma, the anterior belly of the Digastricus, the suprahyoid aponeurosis, the superficial part of the submaxillary gland, the external maxillary and submental vessels, and the mylohyoid vessels and nerve. Its *deep or superior surface* is in relation with the Geniohyoideus, part of the Hyoglossus, and the Styloglossus, the hypoglossal and lingual nerves, the submaxillary ganglion, the sublingual gland, the deep portion of the submaxillary gland and the submaxillary duct, the lingual and sublingual vessels, and the buccal mucous membrane.

Nerve-supply.—The Mylohyoideus is supplied by the mylohyoid branch of the inferior alveolar nerve.

Actions.—Acting from below the Mylohyoideus depresses the front of the mandible; acting from above it raises the hyoid bone and the floor of the mouth.

The **Geniohyoideus** is a narrow muscle, situated above the medial part of the Mylohyoideus. It arises from the inferior mental spine on the back of the symphysis menti, and runs backwards and slightly downwards, to be inserted into the anterior surface of the body of the hyoid bone; it is in contact with its fellow of the opposite side.

Nerve-supply.—The Geniohyoideus is supplied by the first cervical nerve through the hypoglossal nerve.

Actions.—When the Geniohyoideus acts from the hyoid bone, it depresses the front of the mandible; when it acts from the mandible it raises and pulls forwards the hyoid bone.

The infrahyoid muscles are:

Sternohyoideus.	Thyreohyoideus.
Sternothyreoideus.	Omohyoideus.

The **Sternohyoideus**, a thin, narrow muscle, arises from the posterior surface of the medial end of the clavicle, the capsule of the sternoclavicular joint, and the upper and posterior part of the manubrium sterni. Passing upwards and medialwards, it is inserted into the lower border of the body of the hyoid bone. It sometimes presents, immediately above its origin, a transverse tendinous inscription. Below, the Sternohyoideus is separated from its fellow by a considerable interval; but the two muscles come into contact with one another in the middle of their course, and, from this upwards, are contiguous.

Nerve-supply.—The Sternohyoideus is supplied by branches from the loop (ansa hypoglossi) between the descendens hypoglossi and the communicantes cervicales.

Action.—The Sternohyoideus depresses the hyoid bone.

The **Sternothyreoideus** is shorter and wider than the Sternohyoideus, and lies under cover of it. It arises from the posterior surface of the manubrium sterni, below the origin of the Sternohyoideus, and from the edge of the cartilage of the first, and sometimes that of the second, rib; it is inserted into the oblique line on the lamina of the thyreoid cartilage. This muscle is in close contact with its fellow at the lower part of the neck, but diverges somewhat as it ascends; it is occasionally traversed by a transverse or oblique tendinous inscription.

Nerve-supply.—The Sternothyreoideus is supplied by branches from the ansa hypoglossi.

Action.—The Sternothyreoideus draws the larynx down.

The **Thyreohyoideus**, a small, quadrilateral muscle, may be looked upon as an upward continuation of the Sternothyreoideus. It arises from the

oblique line on the lamina of the thyreoid cartilage, and is inserted into the lower border of the greater cornu of the hyoid bone.

Nerve-supply.—The Thyreohyoideus is supplied by a branch from the hypoglossal nerve.

Actions.—The Thyreohyoideus depresses the hyoid bone, or raises the larynx.

The **Omohyoideus** consists of two fleshy bellies united by a central tendon. It arises from the upper border of the scapula, and occasionally from the superior transverse ligament which crosses the scapular notch, its extent of attachment to the scapula varying from a few millimetres to 2·5 cm. From this origin, the *inferior belly* forms a flat, narrow fasciculus, which inclines forwards and slightly upwards across the lower part of the neck, being bound to the clavicle by a fibrous expansion; it then passes behind the Sternocleidomastoideus, becomes tendinous and changes its direction, forming an obtuse angle. It ends in the *superior belly*, which passes almost vertically upwards close to the lateral border of the Sternohyoideus, and is inserted into the lower border of the body of the hyoid bone, lateral to the insertion of the Sternohyoideus. The central tendon of this muscle varies in length and form, and is held in position by a process of the fascia colli, which ensheathes it and is prolonged down to be attached to the clavicle and first rib; it is by this means that the angular form of the muscle is maintained.

Nerve-supply.—The superior belly of the Omohyoideus is supplied by the descendens hypoglossi; the inferior belly by a branch from the ansa hypoglossi.

Actions.—The Omohyoideus depresses the hyoid bone and carries it backwards and lateralwards. The Omohyoidei are concerned also in prolonged inspiratory efforts; by rendering tense the lower part of the fascia colli they lessen the inward suction of the soft parts, which would otherwise compress the great vessels and the apices of the lungs.

The inferior belly of the Omohyoideus divides the posterior triangle of the neck into an upper or *occipital* and a lower or *subclavian* triangle, while its superior belly divides the anterior triangle into an upper or *carotid* and a lower or *muscular* triangle.

III. The Anterior Vertebral Muscles (fig. 544)

Longus colli.	Rectus capitis anterior.
Longus capitis.	Rectus capitis lateralis.

The **Longus colli** is situated on the anterior surface of the vertebral column, between the atlas and the third thoracic vertebra. It is divisible into three portions, a superior oblique, an inferior oblique, and a vertical; its origin and insertion consist of tendinous slips. The *superior oblique portion* arises from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ; it is directed upwards and medialwards, and is inserted by a narrow tendon into the tubercle on the anterior arch of the atlas. The *inferior oblique portion*, the smallest part of the muscle, arises from the front of the bodies of the first two or three thoracic vertebræ; it runs upwards and lateralwards, and is inserted into the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebræ. The *vertical portion* arises from the front of the bodies of the upper three thoracic and lower three cervical vertebræ, and is inserted into the front of the bodies of the second, third, and fourth cervical vertebræ.

Nerve-supply.—The Longus colli is supplied by branches from the anterior divisions of the second, third and fourth cervical nerves.

Actions.—The Longus colli bends the cervical portion of the vertebral column forwards and lateralwards, and slightly rotates it.

The **Longus capitis** (Rectus capitis anticus major), broad and thick above, narrow below, arises by tendinous slips, from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and is inserted into the inferior surface of the basilar part of the occipital bone.

Nerve-supply.—The Longus capitis is supplied by branches from the anterior divisions of the first, second and third cervical nerves.

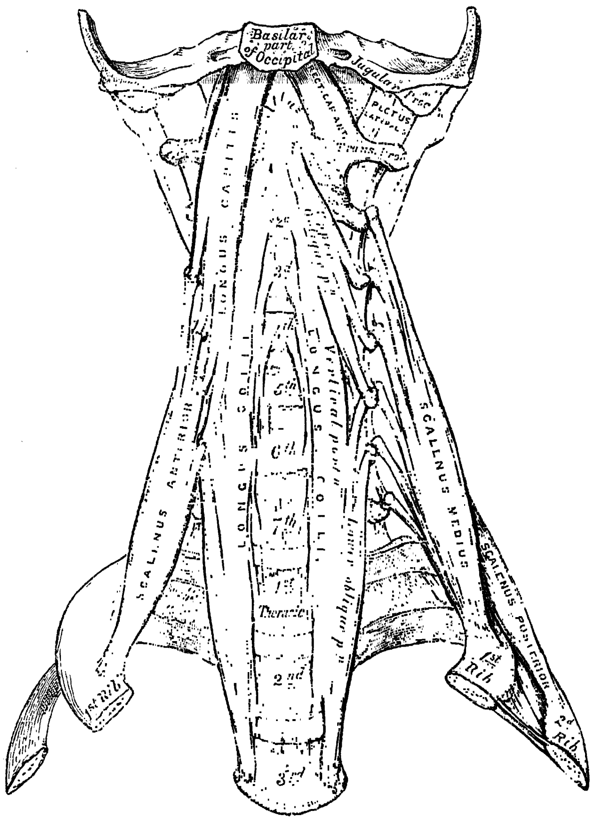
Action.—The Longus capitis flexes the head.

The **Rectus capitis anterior** (Rectus capitis anticus minor) is a short, flat muscle, situated behind the upper part of the Longus capitis. It arises from the anterior surface of the lateral mass of the atlas, and from the root of its transverse process, and is inserted into the inferior surface of the basilar part of the occipital bone in front of the occipital condyle.

Nerve-supply.—The Rectus capitis anterior is supplied by branches from the loop between the anterior divisions of the first and second cervical nerves.

Action.—The Rectus capitis anterior flexes the head.

Fig. 544.—The anterior and lateral vertebral muscles.



The **Rectus capitis lateralis**, a short, flat muscle, arises from the upper surface of the transverse process of the atlas, and is inserted into the under surface of the jugular process of the occipital bone.

Nerve-supply.—The Rectus capitis lateralis is supplied by branches from the loop between the anterior divisions of the first and second cervical nerves.

Action.—The Rectus capitis lateralis bends the head lateralwards.

IV. The Lateral Vertebral Muscles (fig. 544)

Scalenus anterior. Scalenus medius.
Scalenus posterior.

The **Scalenus anterior** lies deeply at the side of the neck, behind the Sternocleidomastoideus. It arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descending, almost vertically, is inserted by a narrow, flat tendon into the scalene tubercle

on the inner border of the first rib, and into the ridge on the upper surface of the rib in front of the subclavian groove.

Relations.—*In front* of it are the clavicle, the Subclavius, Sternocleidomastoideus, and Omohyoideus muscles, the transverse cervical, transverse scapular and ascending cervical arteries, the subclavian vein, and the phrenic nerve. Its *posterior surface* is in relation with the nerves forming the brachial plexus, the subclavian artery, and the pleura, which separate it from the Scalenus medius. Below, it is separated from the Longus colli by the vertebral artery, and above, from the Longus capitis by the ascending cervical branch of the inferior thyreoid artery.

Nerve-supply.—The Scalenus anterior is supplied by branches from the anterior divisions of the fourth, fifth and sixth cervical nerves.

Actions.—Acting from below the Scalenus anterior bends the cervical portion of the vertebral column forwards and lateralwards and rotates it towards the opposite side. When the muscle acts from above it assists in elevating the thorax.

The **Scalenus medius,** the largest and longest of the three Scaleni, arises from the posterior tubercles of the transverse processes of the lower six cervical vertebræ, and descending along the side of the vertebral column, is inserted by a broad attachment into the upper surface of the first rib, between the tubercle of the rib and the subclavian groove.

Relations.—Its *anterior surface* is in relation with the Sternocleidomastoideus; it is crossed by the clavicle and the Omohyoideus; the subclavian artery and the cervical nerves separate it from the Scalenus anterior. *Lateral* to it are the Levator scapulæ and the Scalenus posterior. The long thoracic nerve is formed in the substance of the muscle and emerges from it; the dorsal scapular nerve pierces it.

Nerve-supply.—The Scalenus medius is supplied by branches from the anterior divisions of the cervical nerves.

Actions.—The Scalenus medius, acting from below, bends the cervical part of the vertebral column lateralwards; acting from above it helps to raise the thorax.

The **Scalenus posterior,** the smallest and most deeply seated of the three Scaleni, arises from the posterior tubercles of the transverse processes of the lower two or three cervical vertebræ, and is inserted by a thin tendon into the outer surface of the second rib, behind the attachment of the Serratus anterior. It is occasionally blended with the Scalenus medius.

Nerve-supply.—The Scalenus posterior is supplied by branches from the anterior divisions of the lower three cervical nerves.

Actions.—The Scalenus posterior bends the lower end of the cervical part of the vertebral column lateralwards, when the second rib is fixed; if its upper attachment be fixed it helps to elevate the thorax.

THE FASCIÆ AND MUSCLES OF THE TRUNK

The muscles of the trunk may be arranged in six groups:

I. Deep muscles of the back.
II. Suboccipital muscles.
III. Muscles of the thorax.
IV. Muscles of the abdomen.
V. Muscles of the pelvis.
VI. Muscles of the perinæum.

I. The Deep Muscles of the Back (fig. 546)

The deep or intrinsic muscles of the back consist of a complex group of muscles extending from the pelvis to the skull. They are:

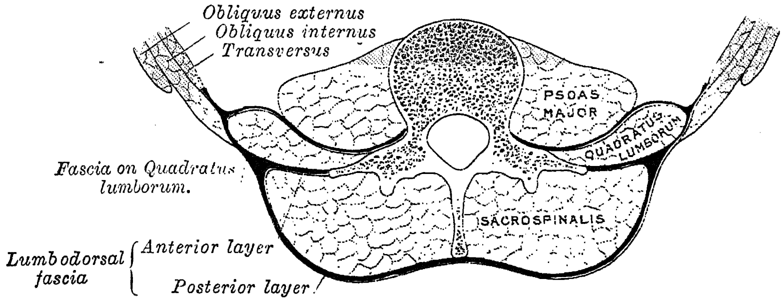
Splenius capitis.
Splenius cervicis.
Sacrospinalis.
Semispinalis.
Multifidus.
Rotatores.
Interspinales.
Intertransversarii.

The **lumbodorsal fascia** covers the deep muscles of the back of the trunk. Above, it passes in front of the Serratus posterior superior and is continuous with the *nuchal fascia*, a similar investing layer on the back of the neck.

In the thoracic region the lumbodorsal fascia is a thin fibrous lamina covering the extensor muscles of the vertebral column and separating them from the muscles connecting the vertebral column to the upper extremity. It contains both longitudinal and transverse fibres, and is attached, *medially*, to the spinous processes of the thoracic vertebræ; *laterally*, to the angles of the ribs.

In the lumbar region the lumbodorsal fascia (lumbar aponeurosis) is in two layers, anterior and posterior (fig. 545). The posterior layer is attached to the spinous processes of the lumbar and sacral vertebræ and to the supraspinal ligament; the anterior is attached, *medially*, to the tips of the transverse processes of the lumbar vertebræ, and to the intertransverse ligaments, *below*, to the iliolumbar ligament, and *above*, to the lumbocostal ligament (p. 369). The two layers unite at the lateral margin of the Sacrospinalis, to form the tendon of origin of the Transversus abdominis.

FIG. 545.—A transverse section through the posterior abdominal wall, to show the disposition of the lumbodorsal fascia. Diagrammatic.



The **Splenius capitis** (fig. 568) arises from the lower half of the ligamentum nuchæ, from the spinous process of the seventh cervical vertebra, and from the spinous processes of the upper three or four thoracic vertebræ. The fibres of the muscle are directed upwards and lateralwards and are inserted, under cover of the Sternocleidomastoideus, into the mastoid process of the temporal bone, and into the rough surface on the occipital bone just below the lateral third of the superior nuchal line.

Nerve-supply.—The Splenius capitis is supplied by lateral branches of the posterior divisions of the middle cervical nerves.

Actions.—The Splenius capitis acts in conjunction with the Splenius cervicis.

The **Splenius cervicis** (fig. 568) arises from the spinous processes of the third to the sixth thoracic vertebræ; it is inserted into the posterior tubercles of the transverse processes of the upper two or three cervical vertebræ.

Nerve-supply.—The Splenius cervicis is supplied by lateral branches of the posterior divisions of the lower cervical nerves.

Actions.—The Splenii of the two sides, acting together, draw the head directly backwards; acting separately, they draw the head to one side, and slightly rotate it, turning the face to the same side.

The **Sacrospinalis** (Erector spinæ) (fig. 546), and its prolongations in the thoracic and cervical regions, lie in the groove on the side of the vertebral column. They are covered in the lumbar and thoracic regions by the lumbodorsal fascia, and in the cervical region by the nuchal fascia. They form a large muscular and tendinous mass which varies in size and structure at different parts of the vertebral column. In the sacral region it is narrow and pointed, and at its origin chiefly tendinous in structure. In the lumbar region it is larger, and forms a thick fleshy mass which, on being followed upwards, is subdivided into three columns; these gradually diminish in size as they ascend to be inserted into the vertebræ and ribs.

The Sacrospinalis arises from the anterior surface of a broad and thick tendon, which is attached to the middle sacral crest, to the spinous processes

of the lumbar and the eleventh and twelfth thoracic vertebræ, to the supraspinal ligament, to the posterior part of the inner lip of the iliac crest and to the lateral crest of the sacrum, where it blends with the sacrotuberous and posterior sacro-iliac ligaments; some of its fibres are continuous with the fibres of origin of the Glutæus maximus. The muscular fibres form a large fleshy mass which splits in the upper lumbar region into three columns, viz. a lateral, the *Iliocostalis*, an intermediate, the *Longissimus*, and a medial, the *Spinalis*. Each of these consists, from below upwards, of three parts, as follows:

Lateral Column.	*Intermediate Column.*	*Medial Column.*
Iliocostalis.	Longissimus.	Spinalis.
(*a*) I. lumborum.	(*a*) L. dorsi.	(*a*) S. dorsi.
(*b*) I. dorsi.	(*b*) L. cervicis.	(*b*) S. cervicis.
(*c*) I. cervicis.	(*c*) L. capitis.	(*c*) S. capitis.

The **Iliocostalis lumborum** is inserted, by flattened tendons, into the inferior borders of the angles of the lower six or seven ribs.

The **Iliocostalis dorsi** (Musculus accessorius) arises from the upper borders of the angles of the lower six ribs medial to the tendons of insertion of the Iliocostalis lumborum; it is inserted into the upper borders of the angles of the upper six ribs and into the back of the transverse process of the seventh cervical vertebra.

The **Iliocostalis cervicis** (Cervicalis ascendens) arises from the angles of the third, fourth, fifth, and sixth ribs, and is inserted into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ.

Nerve-supply.—The Iliocostales are supplied by the posterior divisions of the lower cervical, thoracic, and upper lumbar nerves.

Actions.—The Iliocostales are extensors of the vertebral column; they also bend it to one side. The slips attached to the ribs act as depressors of the thorax.

The **Longissimus dorsi** is the intermediate and largest of the continuations of the Sacrospinalis. In the lumbar region, where it is as yet blended with the Iliocostalis lumborum, some of its fibres are attached to the whole length of the posterior surfaces of the transverse processes and the accessory processes of the lumbar vertebræ, and to the anterior layer of the lumbodorsal fascia. In the thoracic region it is inserted, by rounded tendons, into the tips of the transverse processes of all the thoracic vertebræ, and by fleshy processes into the lower nine or ten ribs between their tubercles and angles.

The **Longissimus cervicis** (Transversalis cervicis), situated medial to the Longissimus dorsi, arises by long thin tendons from the summits of the transverse processes of the upper four or five thoracic vertebræ, and is inserted by similar tendons into the posterior tubercles of the transverse processes of the cervical vertebræ from the second to the sixth inclusive.

The **Longissimus capitis** (Trachelomastoideus) lies between the Longissimus cervicis and the Semispinalis capitis. It arises by tendons from the transverse processes of the upper four or five thoracic vertebræ, and the articular processes of the lower three or four cervical vertebræ, and is inserted into the posterior margin of the mastoid process, beneath the Splenius capitis and Sternocleidomastoideus. It is usually crossed by a tendinous inscription near its insertion.

Nerve-supply.—The Longissimi are supplied by the posterior divisions of the lower cervical, thoracic, and lumbar nerves.

Actions.—The Longissimi dorsi et cervicis bend the vertebral column backwards and lateralwards; the Longissimus capitis extends the head, and turns the face towards the same side.

The **Spinalis dorsi**, the medial continuation of the Sacrospinalis, is scarcely separable as a distinct muscle. It is situated at the medial side of the Longissimus dorsi, and is intimately blended with it; it arises by three or four tendons from the spinous processes of the eleventh and twelfth thoracic, and first and second lumbar, vertebræ: these, uniting, form a small muscle which is inserted by separate tendons into the spinous processes of the upper thoracic vertebræ, the number varying from four to eight. It is intimately united with the Semispinalis dorsi situated beneath it.

present flat, oval facets covered with cartilage, and the bones are connected by an articular capsule and by anterior and posterior ligaments.

The **articular capsule** is attached to the margins of the articular facets on the tibia and fibula; it is much thicker in front than behind. Occasionally the synovial stratum of the capsule is continuous with that of the knee-joint.

The **anterior ligament** of the head of the fibula consists of two or three flat bands, which pass obliquely upwards from the front of the head of the fibula to the front of the lateral condyle of the tibia.

The **posterior ligament** of the head of the fibula is a thick band, which passes obliquely upwards from the back of the head of the fibula to the back of the lateral condyle of the tibia. It is covered by the tendon of the Popliteus.

2. The Crural Interosseous Membrane

The **crural interosseous membrane** connects the interosseous crests of the tibia and fibula, and separates the muscles on the front from those on the back of the leg. It consists of oblique fibres, which for the most part run downwards and lateralwards; a few, however, pass downwards and medialwards. The anterior tibial vessels pass between it and the fibula, about 1 cm. from its upper attachment; in its lower part is an opening for the passage of the perforating branch of the peronæal artery. It is continuous below with the interosseous ligament of the tibiofibular syndesmosis, and presents numerous perforations for the passage of small vessels. It is in relation, in front, with the Tibialis anterior, Extensor digitorum longus, Extensor hallucis longus, Peronæus tertius, and the anterior tibial vessels and deep peronæal nerve; behind, with the Tibialis posterior and Flexor hallucis longus.

3. The Distal Tibiofibular Articulation (Tibiofibular Syndesmosis)

This syndesmosis is formed by the rough, convex surface on the medial side of the lower end of the fibula, and a rough concave surface, the fibular notch, on the lateral side of the tibia. Below, to the extent of about 4 mm., these surfaces are smooth, and covered with cartilage continuous with that of the ankle-joint. The ligaments are: anterior, posterior, inferior transverse, and interosseous.

The **anterior ligament** of the lateral malleolus (fig. 527) is a triangular band, broader below than above, which extends obliquely downwards and lateralwards between the adjacent margins of the tibia and fibula, on the front of the syndesmosis.

The **posterior ligament** of the lateral malleolus (fig. 525), smaller than the preceding, is disposed in a similar manner on the posterior surface of the syndesmosis. Its deep portion forms the **inferior transverse ligament**, a strong, thick band of yellowish fibres which passes transversely across the back of the joint, from the lateral malleolus to the posterior border of the articular surface of the tibia, almost as far as its malleolar process. The inferior transverse ligament projects below the margins of the bones, and forms part of the articulating surface for the talus.

The **interosseous ligament** is continuous, above, with the crural interosseous membrane and consists of numerous short, strong bands, which pass between the adjacent rough surfaces of the tibia and fibula, and constitute the chief bond of union between the bones.

The **synovial stratum** associated with the small arthrodial part of this joint is continuous with that of the ankle-joint.

VI. THE TALOCRURAL ARTICULATION OR ANKLE-JOINT

The ankle-joint is a ginglymus, or hinge-joint. Entering into its formation are the lower end of the tibia and its malleolus, the malleolus of the fibula, and the inferior transverse tibiofibular ligament, which together form a mortise for the reception of the trochlea of the talus. The bones are connected by the following ligaments:

The articular capsule.	Anterior and posterior talofibular.
Deltoid.	Calcaneofibular.

The **Spinalis cervicis** is an inconstant muscle, which arises from the lower part of the ligamentum nuchæ, the spinous process of the seventh cervical, and sometimes from the spinous processes of the first and second thoracic vertebræ, and is inserted into the spinous process of the epistropheus, and occasionally into the spinous processes of the two vertebræ below it.

The **Spinalis capitis** is usually inseparably connected with the Semispinalis capitis.

Nerve-supply.—The Spinales are supplied by the posterior divisions of the lower cervical and thoracic nerves.

Actions.—The Spinales extend the vertebral column.

The **Semispinalis dorsi** consists of thin, fleshy fasciculi, interposed between tendons of considerable length. It arises by a series of tendons from the transverse processes of the thoracic vertebræ from the sixth to the tenth inclusive, and is inserted, by tendons, into the spinous processes of the upper four thoracic and lower two cervical vertebræ.

The **Semispinalis cervicis**, thicker than the preceding, arises by a series of tendinous and fleshy fibres from the transverse processes of the upper five or six thoracic vertebræ, and is inserted into the cervical spinous processes, from the epistropheus to the fifth inclusive. The fasciculus connected with the epistropheus is the largest, and is chiefly muscular in structure.

The **Semispinalis capitis** (Complexus) is situated at the back part of the neck, beneath the Splenius, and medial to the Longissimi cervicis et capitis. It arises by a series of tendons from the tips of the transverse processes of the upper six or seven thoracic and the seventh cervical vertebræ, and from the articular processes of the fourth, fifth, and sixth cervical vertebræ. The tendons are succeeded by a broad muscle which passes upwards and is inserted between the superior and inferior nuchal lines of the occipital bone. The medial part, usually more or less distinct from the remainder of the muscle, is termed the *Spinalis capitis*; it is also named the *Biventer cervicis* since it is traversed by an imperfect tendinous inscription.

Nerve-supply.—The Semispinales are supplied by the posterior divisions of the cervical and thoracic nerves.

Actions.—The Semispinalis dorsi et cervicis extend the thoracic and cervical portions of the vertebral column, and rotate them towards the opposite side; the Semispinalis capitis extends the head, and turns the face slightly towards the opposite side.

The **Multifidus** consists of a number of fleshy and tendinous fasciculi, which fill the groove on the side of the spinous processes of the vertebræ, from the sacrum to the epistropheus. In the sacral region, the fasciculi arise from the back of the sacrum, as low as the fourth sacral foramen, from the aponeurosis of origin of the Sacrospinalis, from the medial surface of the posterior superior iliac spine, and from the posterior sacro-iliac ligaments; in the lumbar region, from all the mamillary processes; in the thoracic region, from all the transverse processes; and in the cervical region, from the articular processes of the lower four vertebræ. Each fasciculus passes obliquely upwards and medialwards and is inserted into the whole length of the spinous process of one of the vertebræ above. The fasciculi vary in length: the most superficial pass from one vertebra to the third or fourth above; those next in order run from one vertebra to the second or third above; while the deepest connect contiguous vertebræ.

Nerve-supply.—The Multifidus is supplied by the posterior divisions of the spinal nerves.

Actions.—The fasciculi of the Multifidus bend the segments of the vertebral column backwards and lateralwards, and rotate them towards the opposite side.

The **Rotatores** lie beneath the Multifidus and are found only in the thoracic region; they are eleven in number on either side, and are small and somewhat quadrilateral in form. Each arises from the upper and posterior part of the transverse process, and is inserted into the lower border and lateral surface of the lamina of the vertebra above, the fibres extending as far as the root of the spinous process. The first is found between the first and second thoracic vertebræ; the last, between the eleventh and twelfth. Sometimes the number of these muscles is diminished by the absence of one or more from the upper or lower end of the series.

Nerve-supply.—The Rotatores are supplied by the posterior divisions of the spinal nerves.

Actions.—The Rotatores mainly rotate the individual vertebræ towards the opposite side.

The **Interspinales** are short muscular fasciculi, placed in pairs between the spinous processes of the contiguous vertebræ, one on either side of the interspinal ligament. In the *cervical region* they are most distinct, and consist of six pairs, the first being situated between the epistropheus and third vertebra, and the last between the seventh cervical and the first thoracic. They are small narrow bundles, attached, above and below, to the apices of the spinous processes. In the *thoracic region* they are found between the first and second vertebræ, and sometimes between the second and third, and the eleventh and twelfth. In the *lumbar region* there are four pairs in the intervals between the five lumbar vertebræ. A pair is occasionally found between the last thoracic and first lumbar, and another between the fifth lumbar and the sacrum.

Nerve-supply.—The Interspinales are supplied by the posterior divisions of the spinal nerves.

Actions.—The Interspinales extend those segments of the vertebral column to which they are attached.

The **Extensor coccygis** is a slender muscular fasciculus, which is not always present; it extends over the lower part of the posterior surface of the sacrum and coccyx. It arises by tendinous fibres from the last segment of the sacrum, or first piece of the coccyx, and passes downwards to be inserted into the lower part of the coccyx. It is a rudiment of the Levator caudæ muscle of the lower animals.

The **Intertransversarii** are small muscles placed between the transverse processes of the vertebræ. In the *cervical region* they are best developed and consist of paired fasciculi which pass between the anterior and the posterior tubercles respectively of the transverse processes of two contiguous vertebræ; the muscles of each pair are separated by the anterior division of the cervical nerve, which lies in the groove between them. The muscles connecting the anterior tubercles are termed the *Intertransversarii anteriores*; those between the posterior tubercles the *Intertransversarii posteriores*. There are seven pairs of these muscles, the first pair being between the atlas and epistropheus, and the last between the seventh cervical and first thoracic vertebræ. In the *thoracic region* they are present between the transverse processes of the lower three thoracic, and between the transverse processes of the last thoracic and the first lumbar vertebræ. In the *lumbar region* they are arranged in pairs, on either side of the vertebral column; one set, occupying the entire interspace between the transverse processes of the lumbar vertebræ, the *Intertransversarii laterales*; the other set, *Intertransversarii mediales*, passing from the accessory process of one vertebra to the mamillary of the vertebra below.

Nerve-supply.—The Intertransversarii mediales are supplied by posterior divisions of the spinal nerves; all the others are supplied by anterior divisions.

Actions.—The Intertransversarii act as lateral flexors of those segments of the vertebral column to which they are attached.

II. The Suboccipital Muscles (fig. 546)

Rectus capitis posterior major.	Obliquus capitis inferior.
Rectus capitis posterior minor.	Obliquus capitis superior.

The **Rectus capitis posterior major** arises by a pointed tendon from the spinous process of the epistropheus and, becoming broader as it ascends, is inserted into the lateral part of the inferior nuchal line of the occipital bone, and also into the bone immediately below the line. As the muscles of the two sides pass upwards and lateralwards, they leave between them a triangular space, in which the Recti capitis posteriores minores are seen.

Nerve-supply.—The Rectus capitis posterior major is supplied by the posterior division of the suboccipital nerve.

Actions.—The Rectus capitis posterior major extends the head, and turns the face towards the same side.

The **Rectus capitis posterior minor** arises by a narrow pointed tendon from the tubercle on the posterior arch of the atlas, and, widening as it ascends, is inserted into the medial part of the inferior nuchal line of the occipital bone and also into the bone between that line and the foramen magnum.

Nerve-supply.—The Rectus capitis posterior minor is supplied by the posterior division of the suboccipital nerve.

Action.—The Rectus capitis posterior minor extends the head.

The **Obliquus capitis inferior**, the larger of the two Oblique muscles, arises from the apex of the spinous process of the epistropheus, and passes lateralwards and slightly upwards, to be inserted into the lower and back part of the transverse process of the atlas.

Nerve-supply.—The Obliquus capitis inferior is supplied by the posterior division of the suboccipital nerve.

Action.—The Obliquus capitis inferior turns the face towards the same side.

The **Obliquus capitis superior**, narrow below, wide and expanded above, arises by tendinous fibres from the upper surface of the transverse process of the atlas, joining with the insertion of the Obliquus capitis inferior. It passes upwards and medialwards, and is inserted into the occipital bone, between the superior and inferior nuchal lines, lateral to the Semispinalis capitis.

Nerve-supply.—The Obliquus capitis superior is supplied by the posterior division of the suboccipital nerve.

Actions.—The Obliquus capitis superior bends the head backwards and lateralwards.

The suboccipital triangle.—This triangle is bounded, above and medially, by the Rectus capitis posterior major; above and laterally, by the Obliquus capitis superior; below and laterally, by the Obliquus capitis inferior. It is covered by a layer of dense fibrofatty tissue, situated beneath the Semispinalis capitis. The floor is formed by the posterior occipito-atlantal membrane, and the posterior arch of the atlas. In the groove on the upper surface of the posterior arch of the atlas are the vertebral artery and the first cervical nerve.

III. The Muscles of the Thorax

Intercostales externi.	Levatores costarum.
Intercostales interni.	Serratus posterior superior.
Subcostales.	Serratus posterior inferior.
Transversus thoracis.	Diaphragm.

The **Intercostales** (fig. 570) are two thin plates of muscular and tendinous fibres occupying each of the intercostal spaces. They are named *external* and *internal* from their surface relations—the external being superficial to the internal.

The **Intercostales externi** are eleven in number on either side. Their attachments extend from the tubercles of the ribs behind, to near the cartilages of the ribs in front, where each is replaced by a layer of fascia named the *anterior intercostal membrane*, which is continued forwards to the sternum. Each muscle arises from the lower border of one rib, and is inserted into the upper border of the rib below. In the lower two spaces they extend to the ends of the rib-cartilages, and in the upper two or three spaces they do not quite reach the ends of the ribs. They are thicker than the Intercostales interni, and their fibres are directed obliquely downwards and lateralwards on the back of the thorax, and downwards, forwards, and medialwards on the front.

The **Intercostales interni** are also eleven in number on either side. Their attachments commence anteriorly at the sternum, in the interspaces between the cartilages of the true ribs, and at the anterior extremities of the cartilages of the false ribs, and extend backwards as far as the angles of the ribs, where each is replaced by a layer of fascia named the *posterior intercostal membrane*, which is continuous with the anterior costotransverse ligament. Each muscle arises from the ridge on the inner surface of one rib, as well as from the corresponding costal cartilage, and is inserted into the upper border of the rib

below. Their fibres are also directed obliquely, but at right angles to those of the Intercostales externi.*

Nerve-supply.—The Intercostales externi et interni are supplied by the intercostal nerves.

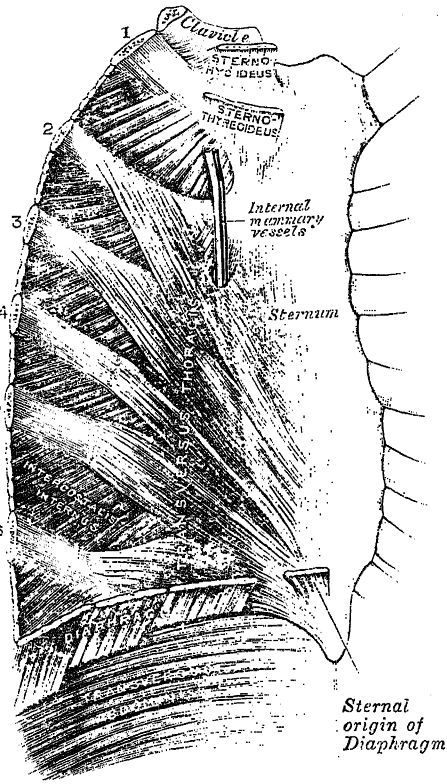
Actions.—The Intercostales externi et interni have probably little action in moving the ribs. They contract simultaneously and form strong elastic supports which prevent the intercostal spaces being drawn in or bulged out during respiration. The anterior portions of the Intercostales interni probably have an additional function in keeping the sternocostal and interchondral joint-surfaces in apposition, the posterior portions of the Intercostales externi performing a similar function for the costovertebral joints.

The **Subcostales** consist of muscular and aponeurotic fasciculi, and are usually well developed only in the lower part of the thorax; each arises from the inner surface of one rib near its angle, and is inserted into the inner surface of the second or third rib below. Their fibres run in the same direction as those of the Intercostales interni.

Nerve-supply.—The Subcostales are supplied by intercostal nerves.

Actions.—The Subcostales depress the ribs.

Fig. 547.—The left Transversus thoracis. Posterior aspect.



The **Transversus thoracis** (Triangularis sterni) is a thin plane of muscular and tendinous fibres, situated upon the inner surface of the front wall of the chest (fig. 547). It arises on either side from the lower third of the posterior surface of the body of the sternum, from the posterior surface of the xiphoid process, and from the posterior surfaces of the costal cartilages of the lower three or four true ribs near their sternal ends. Its fibres diverge upwards and lateralwards, to be inserted by slips into the lower borders and inner surfaces of the costal cartilages of the second, third, fourth, fifth, and sixth ribs. The lowest fibres of this muscle are horizontal, and are continuous with those of the Transversus abdominis; the intermediate fibres are oblique, while the highest are almost vertical. This muscle varies in its attachments not only in different subjects, but on opposite sides of the same subject.

Nerve-supply.—The Transversus thoracis is supplied by intercostal nerves.

Actions.—The Transversus thoracis draws down the costal cartilages to which it is attached.

The **Levatores costarum** (fig. 546), twelve in number on either side, are strong bundles, which arise from the ends of the transverse processes of the seventh cervical and upper eleven thoracic vertebræ; they pass obliquely downwards and lateralwards, parallel with the posterior borders of the Intercostales externi, and each is inserted into the upper edge and outer surface of the rib immediately below the vertebra from which it takes origin, between the

* T. Walmsley (*Journal of Anatomy*, vol. l.) describes each Internal intercostal muscle as consisting of (*a*) a superficial part, confined to the anterior two-thirds of the intercostal space, and properly named the Intercostalis internus, and (*b*) a deep or *intracostal* part, present in about the middle two-fourths of each space, and in the same plane as the Transversus thoracis and the Subcostalis.

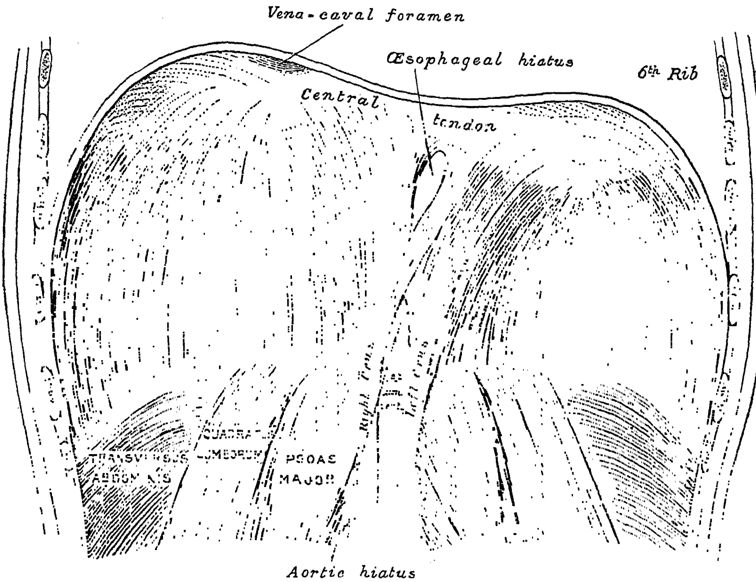
tubercle and the angle (Levatores costarum breves). Each of the four lower muscles divides into two fasciculi, one of which is inserted as above described; the other passes down to the second rib below its origin (Levatores costarum longi).

Nerve-supply.—The Levatores costarum are supplied by the intercostal nerves.

Actions.—The Levatores costarum being inserted near the fulcra of the ribs can have little or no elevating action on the ribs; they act as rotators and lateral flexors of the vertebral column.

The **Serratus posterior superior** is a thin, quadrilateral muscle, situated at the upper and posterior part of the thorax. It arises by a thin aponeurosis from the lower part of the ligamentum nuchæ, from the spinous processes of the seventh cervical and upper two or three thoracic vertebræ and from

FIG. 548.—The posterior one-half of the Diaphragm. Anterior aspect. (Modified from a model by His.)



the supraspinal ligament. Inclining downwards and lateralwards it is inserted, by four fleshy digitations, into the upper borders and outer surfaces of the second, third, fourth, and fifth ribs, a little beyond their angles.

Nerve-supply.—The Serratus posterior superior is supplied by the second, third, fourth and fifth intercostal nerves.

Actions.—The Serratus posterior superior elevates the ribs.

The **Serratus posterior inferior** (fig. 568) is situated at the junction of the thoracic and lumbar regions: it is of an irregularly quadrilateral form, broader than the preceding, and separated from it by a wide interval. It arises by a thin aponeurosis from the spinous processes of the lower two thoracic and upper two or three lumbar vertebræ, and from the supraspinal ligament; this aponeurosis is intimately blended with the lumbodorsal fascia. Passing obliquely upwards and lateralwards, it becomes fleshy, and is inserted by four digitations into the inferior borders and outer surfaces of the lower four ribs, a little beyond their angles.

Nerve-supply.—The Serratus posterior inferior is supplied by the ninth, tenth, eleventh and twelfth thoracic nerves.

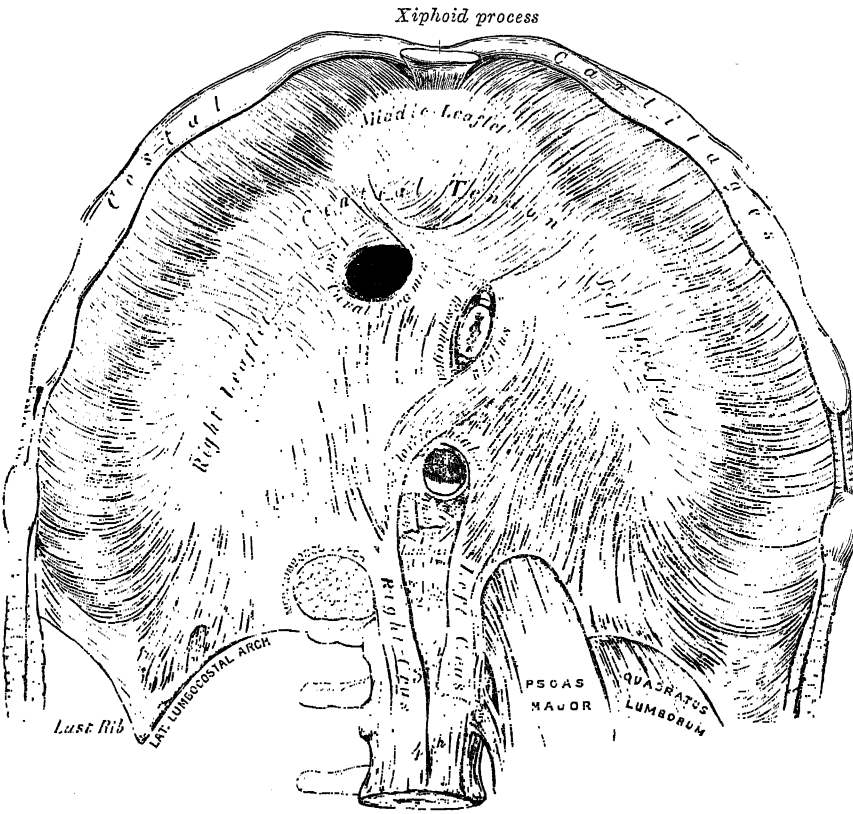
Actions.—The Serratus posterior inferior draws the lower ribs downwards and backwards and thus elongates the thorax; it also fixes the lower ribs, thus assisting the inspiratory action of the Diaphragm and resisting the tendency of the latter to draw the lower ribs upwards and forwards.

The **Diaphragm** (figs. 548, 549) is a dome-shaped musculofibrous septum which separates the thoracic from the abdominal cavity, its convex upper

surface forming the floor of the former, and its concave under surface the roof of the latter. Its peripheral part consists of muscular fibres which take origin from the circumference of the thoracic outlet and converge to be inserted into a central tendon.

The muscular fibres may be grouped according to their origins into three parts—sternal, costal, and lumbar. The *sternal part* arises by two fleshy slips from the back of the xiphoid process; the *costal part* from the inner surfaces of the cartilages and adjacent portions of the lower six ribs on either side, interdigitating with the Transversus abdominis; and the *lumbar part* from aponeurotic arches, named the lumbocostal arches, and from the lumbar vertebræ by two pillars or *crura*. There are two lumbocostal arches, a medial and a lateral, on either side.

Fig. 549.—The Diaphragm. Inferior aspect.



The *medial lumbocostal arch* (internal arcuate ligament) is a tendinous arch in the fascia covering the upper part of the Psoas major; medially, it is continuous with the lateral tendinous margin of the corresponding crus, and is attached to the side of the body of the first or second lumbar vertebræ; laterally, it is fixed to the front of the transverse process of the first lumbar vertebra.

The *lateral lumbocostal arch* (external arcuate ligament) arches across the upper part of the Quadratus lumborum, and is attached, medially, to the front of the transverse process of the first lumbar vertebra, and, laterally, to the lower margin of the twelfth rib.

The crura.—At their origins the crura are tendinous in structure, and blend with the anterior longitudinal ligament of the vertebral column. The *right crus*, larger and longer than the left, arises from the anterior surfaces of the bodies and intervertebral fibrocartilages of the upper three lumbar vertebræ, while the *left crus* arises from the corresponding parts of the upper two only.

The medial tendinous margins of the crura occasionally meet in the middle line to form an arch across the front of the aorta; this arch is often poorly defined.

From this series of origins the fibres of the Diaphragm converge to be inserted into the central tendon. The fibres arising from the xiphoid process are very short, and occasionally aponeurotic; those from the medial and lateral lumbocostal arches, and more especially those from the ribs and their cartilages, are longer, and describe marked curves as they ascend and converge to their insertion. The fibres arising from the crura diverge as they ascend, the most lateral being directed upwards and lateralwards to the central tendon. The medial fibres of the right crus ascend on the left side of the œsophageal hiatus, and occasionally a fasciculus of the left crus crosses the aorta and runs obliquely through the fibres of the right crus towards the venacaval foramen (Low *).

The *central tendon* of the Diaphragm is a thin but strong aponeurosis situated near the centre of the vault formed by the muscle, but somewhat closer to the front than to the back of the thorax, so that the posterior muscular fibres are the longer. It is situated immediately below the pericardium, with which it is partially blended. It is shaped somewhat like a trefoil leaf, consisting of three divisions or leaflets separated from one another by slight indentations. The right leaflet is the largest, the middle, directed towards the xiphoid process, the next in size, and the left the smallest. In structure the tendon is composed of several planes of fibres, which intersect one another at various angles and unite into straight or curved bundles—an arrangement which gives it additional strength.

Openings in the Diaphragm.—The Diaphragm is pierced by a series of apertures to permit of the passage of structures between the thorax and abdomen. Three large openings—the aortic, the œsophageal, and the vena-caval—and a number of smaller ones are present.

The *aortic hiatus* is the lowest and most posterior of the large apertures; it lies at the level of the twelfth thoracic vertebra slightly to the left of the middle line. Strictly speaking, it is an osseo-aponeurotic opening between the vertebral column and the Diaphragm, and therefore behind the latter; occasionally some tendinous fibres from the medial parts of the crura pass behind the aorta, and convert the hiatus into a fibrous ring. Through it pass the aorta, the azygos vein, and the thoracic duct; occasionally the azygos vein pierces the right crus.

The *œsophageal hiatus* is situated in the muscular part of the Diaphragm at the level of the tenth thoracic vertebra; it is elliptical in shape, and is "formed by the splitting of the medial fibres of the right-crus" (Low). It is placed above, in front, and a little to the left of the aortic hiatus, and transmits the œsophagus, the vagus nerves, and some small œsophageal vessels.

The *venacaval foramen* is the highest of the three, and is situated about the level of the fibrocartilage between the eighth and ninth thoracic vertebræ. It is quadrilateral in form, and is placed at the junction of the right and middle leaflets of the central tendon, so that its margins are tendinous. It transmits the inferior vena cava, the wall of which is adherent to the margin of the opening, and some branches of the right phrenic nerve.

Of the *lesser apertures*, two in the right crus transmit the greater and lesser right splanchnic nerves; three in the left crus give passage to the greater and lesser left splanchnic nerves and the hemiazygos vein. The gangliated trunks of the sympathetic usually enter the abdominal cavity behind the Diaphragm, under the medial lumbocostal arches. The structures piercing the crura are sometimes utilised to divide each crus into medial, intermediate, and lateral parts, the last consisting of the fibres arising from the medial lumbocostal arch. Between the medial and intermediate parts the hemiazygos vein and the splanchnic nerves pass; between the intermediate and lateral parts the gangliated trunks of the sympathetic occasionally pass.

On either side two small intervals exist at which the muscular fibres of the Diaphragm are deficient and are replaced by areolar tissue. One between the sternal and costal parts transmits the superior epigastric branch of the internal mammary artery, and some lymphatics from the abdominal wall and

* Alex. Low, *Journal of Anatomy and Physiology*, vol. xlii.

convex surface of the liver. The other, between the fibres springing from the medial and lateral lumbocostal arches, is less constant; when this interval exists, the upper and back part of the kidney is separated from the pleura by areolar tissue only.

Relations.—The upper surface of the Diaphragm is in relation with three serous membranes, viz. on either side the pleura, which separates it from the base of the corresponding lung, and on the middle leaflet of the central tendon the pericardium, which intervenes between it and the heart. The central portion lies on a slightly lower level than the summits of the lateral portions. The greater part of the under surface is covered by the peritoneum. The right side is accurately moulded over the convex surface of the right lobe of the liver, the right kidney, and right suprarenal gland; the left over the left lobe of the liver, the fundus of the stomach, the spleen, the left kidney, and the left suprarenal gland.

Nerve-supply.—The Diaphragm is supplied by the phrenic nerve and the lower six or seven intercostal nerves.

Actions.—The Diaphragm is the principal muscle of inspiration, and presents the form of a dome concave towards the abdomen. The central part of the dome is tendinous, and the pericardium is attached to its upper surface; the circumference is muscular. During inspiration the lowest ribs are fixed, and from these and the crura the muscular fibres contract and draw downwards and forwards the central tendon with the attached pericardium. In this movement the curvature of the Diaphragm is scarcely altered, the dome moving downwards nearly parallel to its original position and pushing before it the abdominal viscera. The descent of the abdominal viscera is permitted by the extensibility of the abdominal wall, but the limit of this is soon reached. The central tendon applied to the abdominal viscera then becomes a fixed point for the action of the Diaphragm, the effect of which is to elevate the lower ribs and through them to push forwards the body of the sternum and the upper ribs. The right cupola of the Diaphragm, lying on the liver, has a greater resistance to overcome than the left, which lies over the stomach, but to compensate for this the right crus and the fibres of the right side generally are stronger than those of the left.

In all expulsive acts the Diaphragm is called into action to give additional power to each effort. Thus, before sneezing, coughing, laughing, crying, or vomiting, and previous to the expulsion of urine or fæces, or of the fœtus from the uterus, a deep inspiration takes place.

The height of the Diaphragm is constantly varying during respiration; it also varies with the degree of distension of the stomach and intestines and with the size of the liver. After a forced expiration the right cupola is on a level in front with the fourth costal cartilage, at the side with the fifth, sixth, and seventh ribs, and behind with the eighth rib; the left cupola is a little lower than the right. Halls Dally * states that the absolute range of movement between deep inspiration and deep expiration averages in the male and female 30 mm. on the right side and 28 mm. on the left; in quiet respiration the average movement is 12·5 mm. on the right side and 12 mm. on the left.

Skiagraphy shows that the height of the Diaphragm in the thorax varies considerably with the position of the body. It stands highest when the body is horizontal and the patient on his back, and in this position it performs the largest respiratory excursions with normal breathing. When the body is erect the dome of the Diaphragm falls, and its respiratory movements become smaller. The dome falls still lower when the sitting posture is assumed, and in this position its respiratory excursions are smallest. When the body is horizontal and the patient on his side, the two halves of the Diaphragm do not behave alike. The uppermost half sinks to a level lower even than when the patient sits, and moves little with respiration; the lower half rises higher in the thorax than it does when the patient is supine, and its respiratory excursions are much increased.

It appears that the position of the Diaphragm in the thorax depends upon three main factors, viz.: (1) the elastic retraction of the lung-tissue, tending to pull it upwards; (2) the pressure exerted on its under surface by the viscera: this naturally tends to be a negative pressure, or downward suction, when the patient sits or stands, and a positive, or upward pressure, when he lies; (3) the intra-abdominal tension due to the abdominal muscles. These muscles are in a state of contraction in the standing position and not in the sitting; hence the Diaphragm is pushed up higher in the former position.

* *Journal of Anatomy and Physiology*, vol. xliii.

Applied Anatomy.—The oblique rise of the Diaphragm from the costal margin to the level of the fifth costal cartilage on the right side, and the sixth on the left, has to be borne in mind in opening an empyema. If the drainage tube be put in too low down, when the abscess cavity contracts the Diaphragm is drawn up against and blocks the tube before the abscess is cured.

The Mechanism of Respiration

The respiratory movements must be examined during (*a*) quiet respiration, and (*b*) deep respiration.

Quiet respiration.—The first and second pairs of ribs are fixed by the resistance of the cervical structures; the last pair, and through them the eleventh, by the Quadratus lumborum. The other ribs are elevated, so that the first two intercostal spaces are diminished while the others are increased in width. It has already been shown (p. 373) that elevation of the third, fourth, fifth, and sixth ribs leads to an increase in the anteroposterior and transverse diameters of the thorax: the vertical diameter is increased by the descent of the diaphragmatic dome so that the lungs are expanded in all directions except backwards and upwards. Elevation of the eighth, ninth, and tenth ribs is accompanied by a lateral and backward movement, leading to an increase in the transverse diameter of the upper part of the abdomen; the elasticity of the anterior abdominal wall allows a slight increase in the antero-posterior diameter of this part, and in this way the decrease in the vertical diameter of the abdomen is compensated and space provided for its displaced viscera. Expiration is effected by the elastic recoil of its walls and by the action of the abdominal muscles, which push back the viscera displaced downwards by the Diaphragm.

Deep respiration.—All the movements of quiet respiration are here carried out, but to a greater extent. In deep respiration the shoulders and the vertebral borders of the scapulæ are fixed and the limb muscles, the Trapezius, Serratus anterior, Pectorales, and Latissimus dorsi, called into play. The Scaleni are in strong action, and the Sternocleidomastoidei also assist, when the head is fixed, by drawing up the sternum and by fixing the clavicles. The first rib is therefore no longer stationary, but, with the sternum, is raised; with it all the other ribs except the last are raised to a higher level. In conjunction with the increased descent of the Diaphragm this provides for a considerable augmentation of all the thoracic diameters. The anterior abdominal muscles come into action so that the umbilicus is drawn upwards and backwards, but this allows the Diaphragm to exert a more powerful influence on the lower ribs; the transverse diameter of the upper part of the abdomen is greatly increased and the subcostal angle opened out. The deeper muscles of the back, e.g. the Serrati posteriores superiores and the Sacrospinales and their continuations, are also brought into action; the thoracic curve of the vertebral column is partially straightened, and the whole column, above the lower lumbar vertebræ, drawn backwards. This increases the anteroposterior diameters of the thorax and upper part of the abdomen and widens the intercostal spaces. Deep expiration is effected by the recoil of the walls and by the contraction of the anterolateral muscles of the abdominal wall, and the Transversus thoracis.

Halls Dally (*loc. cit.*) gives the following figures as representing the average changes which occur during deepest possible respiration. The manubrium sterni moves 30 mm. in an upward and 14 mm. in a forward direction; the width of the subcostal angle, at a level of 30 mm. below the articulation between the body of the sternum and the xiphoid process, is increased by 26 mm.; the umbilicus is retracted and drawn upwards for a distance of 18 mm.

Applied Anatomy.—The changes in the height of the Diaphragm during alterations in posture explain why patients suffering from severe dyspnœa are most comfortable and least short of breath when they sit up. In unilateral disease of the pleura or lungs interference with the position or movement of the Diaphragm can generally be observed skiagraphically.

The referred pains felt when the Diaphragm is inflamed are described with the anatomy of the phrenic nerve.

IV. The Muscles of the Abdomen

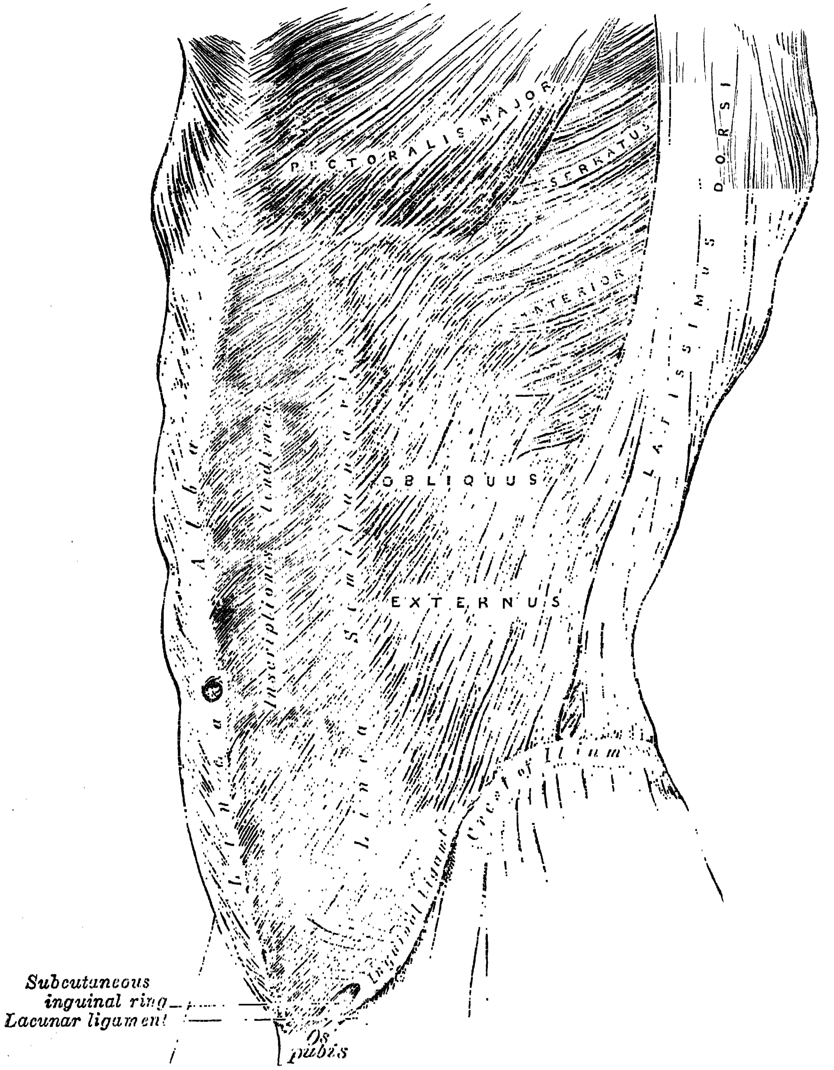
The muscles of the abdomen may be divided into two groups: 1. The anterolateral muscles; 2. The posterior muscles.

1. The Anterolateral Muscles

Obliquus externus. Transversus.
Obliquus internus. Rectus.
Pyramidalis.

The **superficial fascia** of the abdomen consists, over the greater part of the abdominal wall, of a single layer containing a variable amount of fat; but

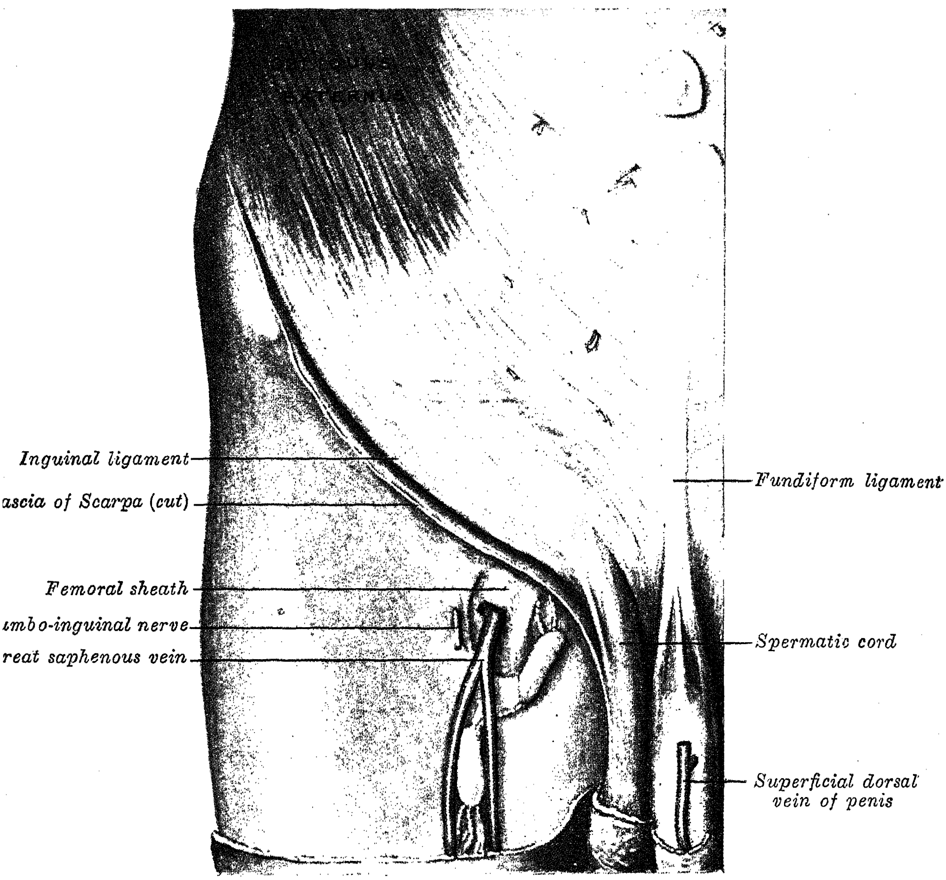
Fig. 550.—The left Obliquus externus abdominis.



near the groin it is easily divisible into two layers, between which are found the superficial vessels and nerves and the superficial inguinal lymph-glands.

The superficial layer (*fascia of Camper*) is thick, areolar in texture, and contains in its meshes a varying quantity of adipose tissue. Below, it passes over the inguinal ligament, and is continuous with the superficial fascia of the thigh. In the male, Camper's fascia is continued over the penis and outer surface of the spermatic cord to the scrotum, where it helps to form the dartos. As it passes to the scrotum it changes its characteristics, becoming thin, destitute of adipose tissue, and of a pale reddish colour; in the scrotum it acquires some involuntary muscular fibres and forms the *dartos tunic*. From the scrotum

FIG. 551.—A superficial dissection of the groin and the lower part of the anterior abdominal wall. Right side.



it may be traced backwards into continuity with the superficial fascia of the perinæum. In the female, Camper's fascia is continued from the abdomen into the labia majora.

The deep layer (*fascia of Scarpa*) is thinner and more membranous in character than the superficial layer, and contains a considerable quantity of elastic fibres. It is loosely connected by areolar tissue to the aponeurosis of the Obliquus externus abdominis, but in the middle line it is more intimately adherent to the linea alba and to the symphysis pubis, and is prolonged on to the dorsum of the penis, forming the *fundiform ligament*; above, it is continuous with the superficial fascia over the rest of the trunk; below and laterally, it blends with the fascia lata of the thigh a little below and parallel with the inguinal ligament (fig. 551); below and medially, it is continued over the penis and spermatic cord to the scrotum, where it helps to form the dartos. From the scrotum it may be traced backwards into continuity with the deep layer of the superficial fascia of the perinæum (*fascia of Colles*). In the female, it is continued into the labia majora and thence to the fascia of Colles.

labii inferioris) on either side of the middle line; this slip arises from the mandible, lateral to the Mentalis, and intermingles with the other muscles at the angle of the mouth.

Nerve-supply.—The Orbicularis oris is supplied by the buccal and mandibular branches of the facial nerve.

Actions.—The Orbicularis oris in its ordinary action effects the direct closure of the lips; by its deep, assisted by its oblique, fibres, it compresses the lips against the teeth. The superficial part, consisting principally of the decussating fibres, brings the lips together and protrudes them.

The **Risorius** arises from the parotideomasseteric fascia and is inserted into the skin at the angle of the mouth (fig. 534). It is a narrow bundle of fibres, broadest at its origin, but varying much in its size and form.

Nerve-supply.—The Risorius is supplied by the buccal branches of the facial nerve.

Actions.—The Risorius retracts the angle of the mouth, and produces an unpleasant grinning expression.

V. The Muscles of Mastication

Masseter.	Pterygoideus externus.
Temporalis.	Pterygoideus internus.

Covering the Masseter, and firmly connected with it, is a strong layer of fascia derived from the fascia colli and named the **parotideomasseteric fascia.** It is attached to the lower border of the zygomatic arch, and invests the parotid gland (p. 448).

The **Masseter** (fig. 534) is a quadrilateral muscle, consisting of two portions, superficial and deep. The *superficial portion*, the larger, arises by a thick aponeurosis from the zygomatic process of the maxilla, and from the anterior two-thirds of the lower border of the zygomatic arch; its fibres pass downwards and backwards, to be inserted into the angle and lower one-half of the lateral surface of the ramus of the mandible. The *deep portion* is much smaller and is partly concealed by the superficial portion; it arises from the posterior one-third of the lower border and from the whole of the medial surface of the zygomatic arch; its fibres pass downwards and forwards, to be inserted into the lateral surfaces of the coronoid process and the upper one-half of the ramus of the mandible.

Relations.—*Superficial* to the muscle are the integument, the Platysma, the Risorius, the Zygomaticus, and the parotid gland; the parotid duct, branches of the facial nerve, and the transverse facial vessels cross the muscle. The *deep surface* is in relation with the insertion of the Temporalis and the ramus of the mandible; a mass of fat separates it from the Buccinator muscle and nerve. The masseteric nerve and artery enter the muscle on its deep surface. The *posterior margin* is overlapped by the parotid gland; the *anterior margin* projects over the Buccinator and is crossed below by the anterior facial vein.

Nerve-supply.—The Masseter is supplied by the masseteric branch of the anterior trunk of the mandibular nerve.

Actions.—The Masseter pulls the mandible towards and against the maxillæ; from its relation to the axis of movement it can act with very great force.

The **temporal fascia** covers the Temporalis. It is a strong, fibrous investment, covered, laterally, by the Auriculares anterior et superior, the galea aponeurotica, and a part of the Orbicularis oculi. The superficial temporal vessels and the auriculotemporal nerve cross it from below upwards. Above, it is a single layer, attached to the entire extent of the superior temporal line; below, it consists of two layers, one of which is attached to the lateral, and the other to the medial border of the zygomatic arch. A small quantity of fat, the zygomatico-orbital branch of the superficial temporal artery, and the zygomaticotemporal branch of the maxillary nerve, are contained between these two layers. The deep surface of the fascia affords attachment to the superficial fibres of the Temporalis.

The **Temporalis** (fig. 539) is a fan-shaped muscle, situated at the side of the head. It arises from the whole of the temporal fossa (except the portion formed by the zygomatic bone) and from the deep surface of the temporal

The margin of that portion of the aponeurosis which extends between the anterior superior iliac spine and the pubic tubercle is a thick band, folded inwards upon itself to present a grooved upper surface, and continuous below with the fascia lata; it is called the *inguinal ligament*. A small portion is reflected from the medial part of the inguinal ligament, and is attached to the pecten pubis; it is called the *lacunar ligament*. From the attachment of the latter to the pecten pubis, a few fibres pass upwards and medialwards, behind the medial crus of the subcutaneous inguinal ring, to the linea alba; they diverge as they ascend, and form a thin triangular fibrous band which is called the *reflected inguinal ligament* (fig. 557).

In the aponeurosis of the Obliquus externus, immediately above the crest of the os pubis, is a triangular opening, the *subcutaneous inguinal ring*, formed by a separation of the fibres of the aponeurosis in this situation.

Nerve-supply.—The Obliquus externus abdominis is supplied by the anterior divisions of the lower thoracic nerves.

Actions.—When the thorax and pelvis are fixed the Obliqui externi abdominis compress the abdominal viscera and thus assist in expelling the fæces from the rectum, the urine from the bladder, the fœtus from the uterus, and the contents of the stomach in vomiting. If the pelvis and vertebral column be fixed the muscles depress and compress the lower part of the thorax, assisting in expiration. If the pelvis alone be fixed, the trunk is bent forwards when both muscles act; if the muscle of one side act, the trunk is bent towards that side and the front of the abdomen turned towards the opposite side. If the thorax be fixed the muscles, acting together, draw the front of the pelvis upwards; acting singly they will in addition bend the lumbar part of the vertebral column, and turn the front of the abdomen to the same side.

The following structures require further description, viz. the subcutaneous inguinal ring, the intercrural fibres and fascia, and the inguinal, lacunar, and reflected inguinal ligaments.

The **subcutaneous inguinal ring** (external abdominal ring) (figs. 550, 552) is an interval in the aponeurosis of the Obliquus externus, just above and lateral to the crest of the os pubis. The aperture is somewhat triangular in form, and its direction is oblique, corresponding with the course of the fibres of the aponeurosis. It measures from base to apex about 2·5 cm., and across the base about 1·25 cm. It is bounded below by the crest of the os pubis; on either side by the margins of the opening in the aponeurosis, which are called the *crura of the ring*; and above, by a series of curved *intercrural fibres*. The inferior crus (external pillar) is the stronger, and is formed by that portion of the inguinal ligament which is inserted into the pubic tubercle; it is so curved as to form a kind of groove, upon which, in the male, the spermatic cord rests. The superior crus (internal pillar) is a thin, flat band, attached to the front of the symphysis pubis and interlacing with its fellow of the opposite side.

The subcutaneous inguinal ring gives passage to the spermatic cord and ilio-inguinal nerve in the male, and to the round ligament of the uterus and the ilio-inguinal nerve in the female; it is much larger in men than in women, on account of the size of the spermatic cord.

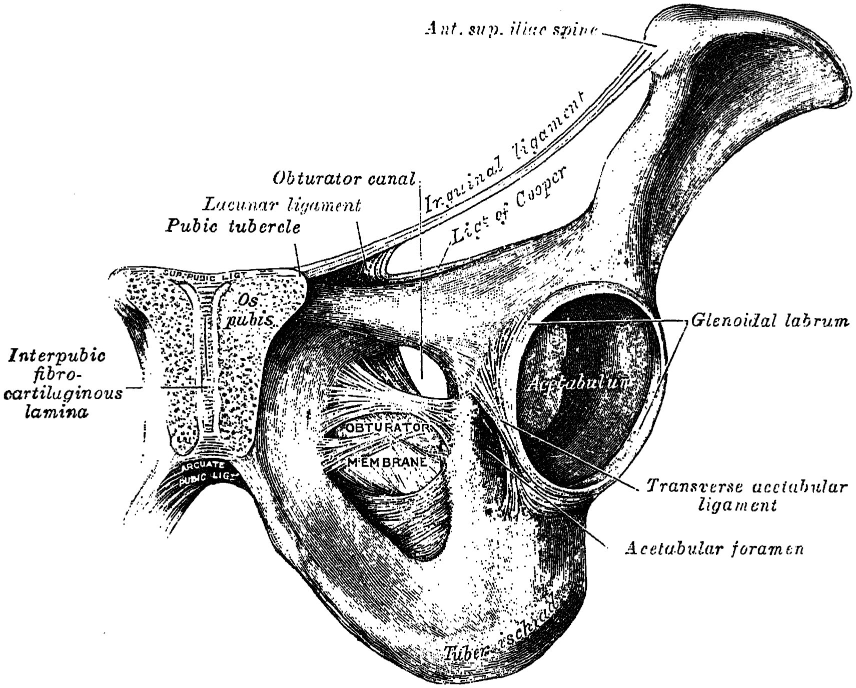
The **intercrural fibres** (intercolumnar fibres) are a series of curved tendinous fibres, which arch across the lower part of the aponeurosis of the Obliquus externus, describing curves with the convexities downwards. They have received their name from stretching across between the two crura of the subcutaneous inguinal ring, and they are much thicker and stronger at the inferior crus, where they are connected to the inguinal ligament, than superiorly, where they are inserted into the linea alba. The intercrural fibres increase the strength of the lower part of the aponeurosis, and tend to prevent the divergence of the crura from one another; they are more strongly developed in the male than in the female.

As they pass across the subcutaneous inguinal ring, they are connected together by delicate fibrous tissue, forming a fascia, called the *intercrural fascia*. This **intercrural fascia** is continued down as a tubular prolongation around the spermatic cord and testis, and encloses them in a sheath; hence it is also called the *external spermatic fascia*. The subcutaneous inguinal ring is seen as a distinct aperture only after the intercrural fascia has been removed.

The **inguinal ligament** (Poupart's ligament) (figs. 551 to 553) is the lower border of the aponeurosis of the Obliquus externus, and extends from the anterior superior iliac spine to the pubic tubercle. Its general direction is convex downwards towards the thigh, where it is continuous with the fascia lata. Its lateral one-half is rounded, and oblique in direction; its medial one-half gradually widens at its attachment to the os pubis, is more horizontal in direction, and supports the spermatic cord.

The **lacunar ligament** (Gimbernat's ligament) (fig. 553) is that portion of the aponeurosis of the Obliquus externus which is reflected backwards and lateralwards from the medial part of the inguinal ligament, and is attached to the pecten pubis. It is of a triangular form, and is almost horizontal in direction

FIG. 553.—The left inguinal and lacunar ligaments.



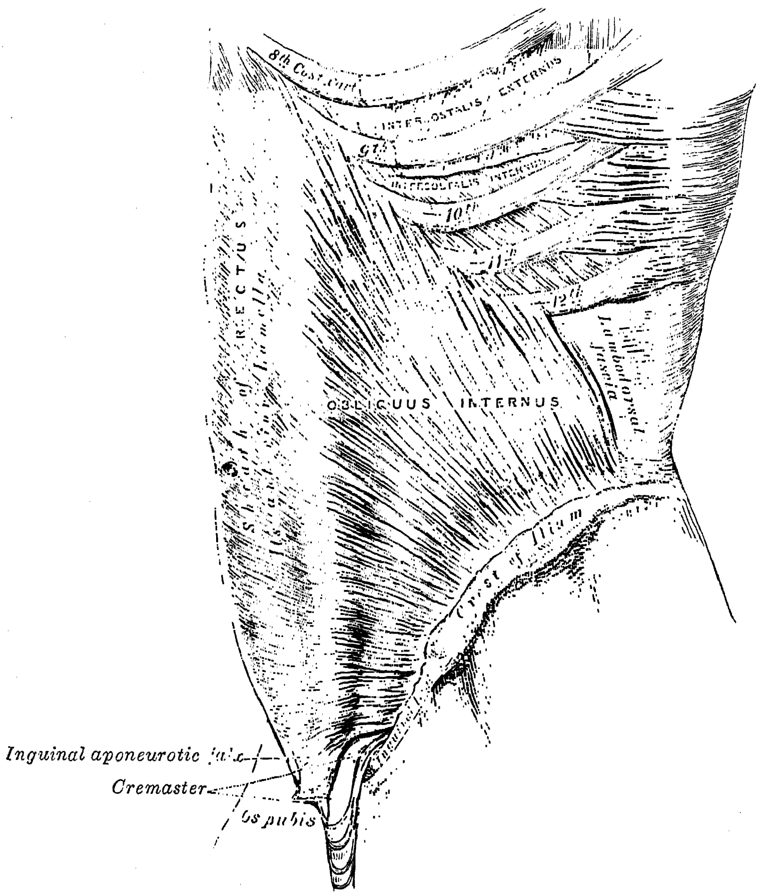
when the body is in the erect posture; it is a little larger in the male than in the female, and measures about 2 cm. from base to apex. Its base, directed laterally, is concave and thin and forms the medial boundary of the femoral ring; its apex corresponds to the pubic tubercle. Its posterior margin is attached to the pecten pubis, and is continuous with the pectineal fascia; its anterior margin blends with the inguinal ligament. Its surfaces are directed upwards and downwards.

The **reflected inguinal ligament** (triangular fascia) (figs. 552, 557) is a triangular-shaped layer of tendinous fibres; it is formed by an expansion from the lacunar ligament and the inferior crus of the subcutaneous inguinal ring. It passes medialwards behind the spermatic cord, expands into a somewhat fan-shaped band behind the superior crus of the subcutaneous inguinal ring and in front of the inguinal aponeurotic falx, and interlaces with the ligament of the other side at the linea alba.

Ligament of Cooper.—This is a strong fibrous band, which was first described by Sir Astley Cooper. It extends lateralwards from the base of the lacunar ligament (fig. 553) along the pecten pubis, to which it is attached. It is strengthened by the pectineal fascia, and by a lateral expansion from the lower attachment of the linea alba (adminiculum lineæ albæ).

The **Obliquus internus abdominis** (fig. 554), thinner and smaller than the Obliquus externus, beneath which it lies, is of an irregularly quadrilateral form. It arises, by fleshy fibres, from the lateral one-half of the grooved upper surface of the inguinal ligament, from the anterior two-thirds of the middle lip of the iliac crest, and from the posterior lamella of the lumbodorsal fascia. From this origin the fibres diverge ; those from the inguinal ligament, few in number, and paler in colour than the rest, arch downwards and medialwards across the spermatic cord in the male, and the round ligament of the uterus in the female, and, becoming tendinous, are inserted, conjointly with those of

FIG. 554.—The left Obliquus internus abdominis.



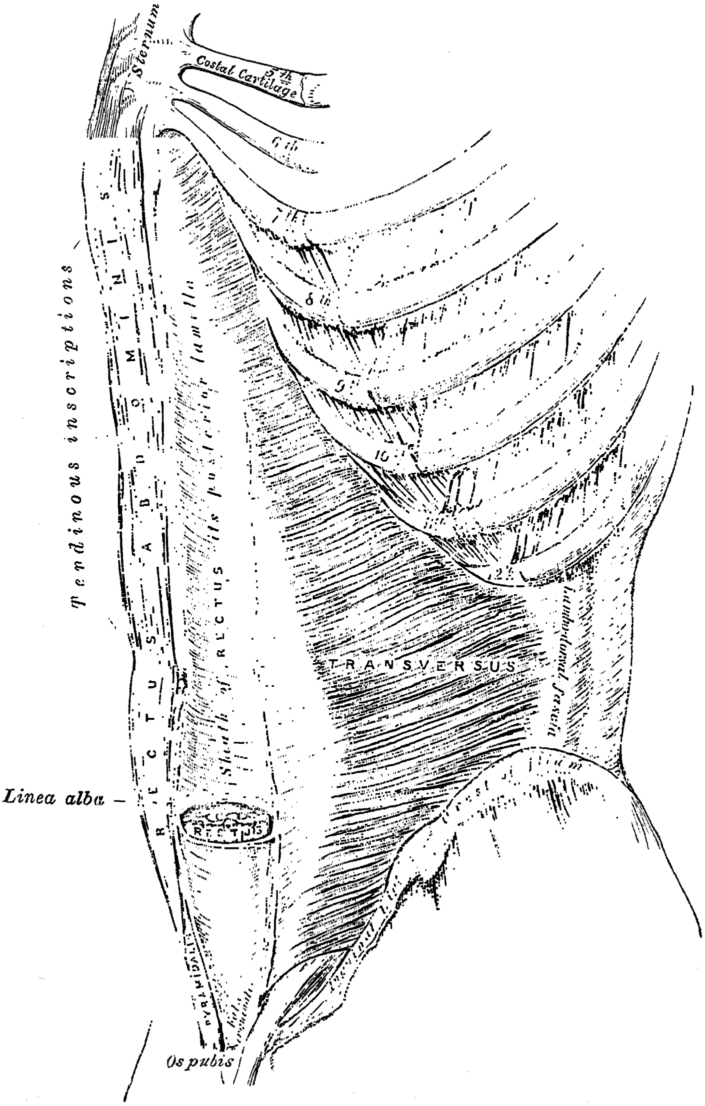
the Transversus, into the crest of the os pubis and into the medial part of the pecten pubis behind the lacunar ligament, forming what is known as the inguinal aponeurotic falx. Those from the anterior one-third of the iliac origin are horizontal in their direction, and, becoming tendinous along the lower one-fourth of the linea semilunaris, pass in front of the Rectus abdominis to be inserted into the linea alba. Those arising from the middle one-third of the iliac origin run obliquely upwards and medialwards, and end in an aponeurosis ; this divides at the lateral border of the Rectus into two lamellæ, which are continued forwards, one in front of and the other behind this muscle, to the linea alba ; the posterior lamella has an attachment to the cartilages of the seventh, eighth, and ninth ribs. The most posterior fibres pass almost vertically upwards, to be inserted into the inferior borders of the cartilages of the lower three ribs, being continuous with the Intercostales interni.

Nerve-supply.—The Obliquus internus abdominis is supplied by the anterior divisions of the lower thoracic and first lumbar nerves.

Actions.—The actions of the Obliqui interni abdominis are similar to those of the Obliqui externi in compressing the abdomen (p. 472). Acting from below the Obliquus internus bends the thorax and turns the front of the abdomen towards the same side; acting from above it bends the lumbar part of the vertebral column to its own side and turns the front of the abdomen to the opposite side.

The **Cremaster** (figs. 554, 556) is a thin muscular layer, composed of a number of fasciculi which arise from the middle of the inguinal ligament, where

Fig. 555.—The left Transversus abdominis and right Rectus abdominis.



its fibres are continuous with those of the Obliquus internus and also occasionally with the Transversus. It passes along the lateral side of the spermatic cord, descends with it through the subcutaneous inguinal ring upon the front and sides of the cord, and forms a series of loops which differ in thickness and length in different subjects. At the upper part of the cord the loops are short, but they become successively longer, the longest reaching down as far as the testis, where a few are inserted into the tunica vaginalis. These loops are united together by areolar tissue, and form a thin covering over the cord and testis, the *cremasteric fascia*. The fibres ascend along the medial side of the

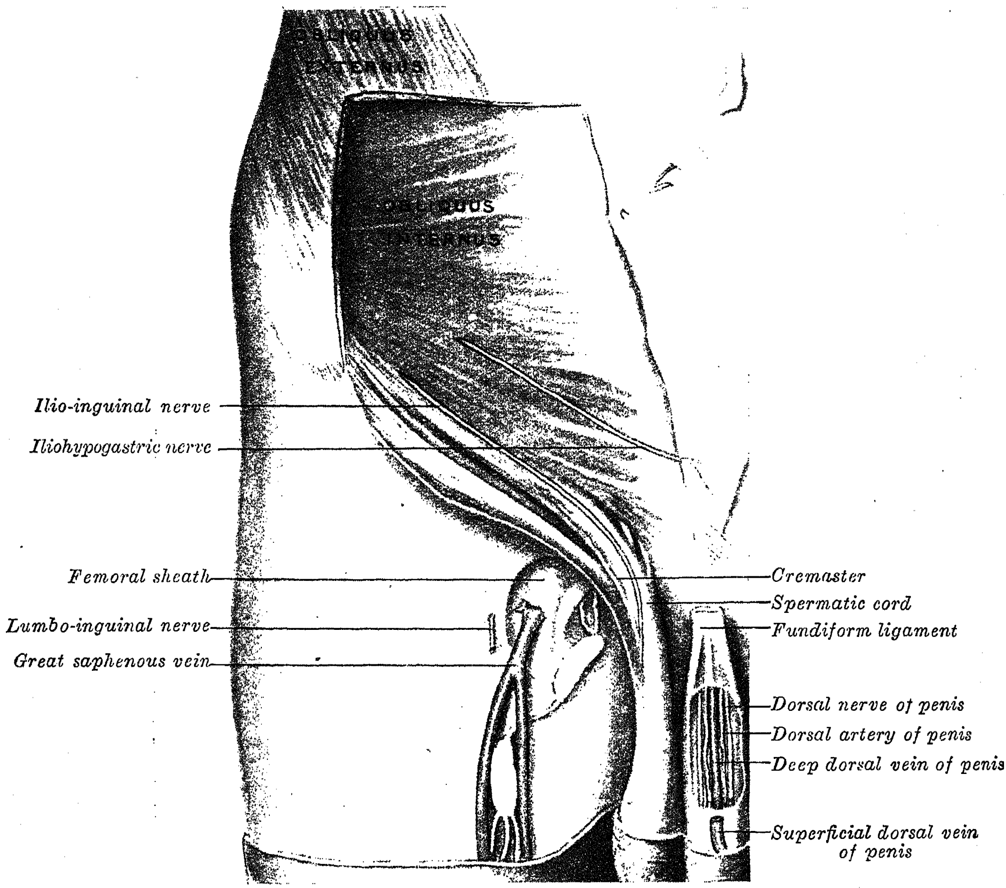
cord, and are inserted by a small pointed tendon into the tubercle and crest of the os pubis and into the front of the sheath of the Rectus abdominis.

Nerve-supply.—The Cremaster is supplied by the external spermatic branch of the genitofemoral nerve.

Action.—The Cremaster is an involuntary muscle which pulls up the testis.

The **Transversus abdominis** (fig. 555), so called from the direction of its fibres, is the most internal of the flat muscles of the abdomen, being situated deep to the Obliquus internus. It arises by fleshy fibres from the lateral

FIG. 556.—A dissection of the regions shown in fig. 551, but with a part of the Obliquus externus removed.



one-third of the inguinal ligament, from the anterior three-fourths of the inner lip of the iliac crest, from the inner surfaces of the cartilages of the lower six ribs, interdigitating with the Diaphragm, and from the lumbodorsal fascia. The muscle ends in front in a broad aponeurosis, the lower fibres of which curve downwards and medialwards, and are inserted, together with those of the Obliquus internus, into the crest of the os pubis and pecten pubis, forming the inguinal aponeurotic falx. Throughout the rest of its extent the aponeurosis passes horizontally to the middle line, and is inserted into the linea alba; its upper three-fourths lie behind the Rectus and blend with the posterior lamella of the aponeurosis of the Obliquus internus; its lower one-fourth is in front of the Rectus.

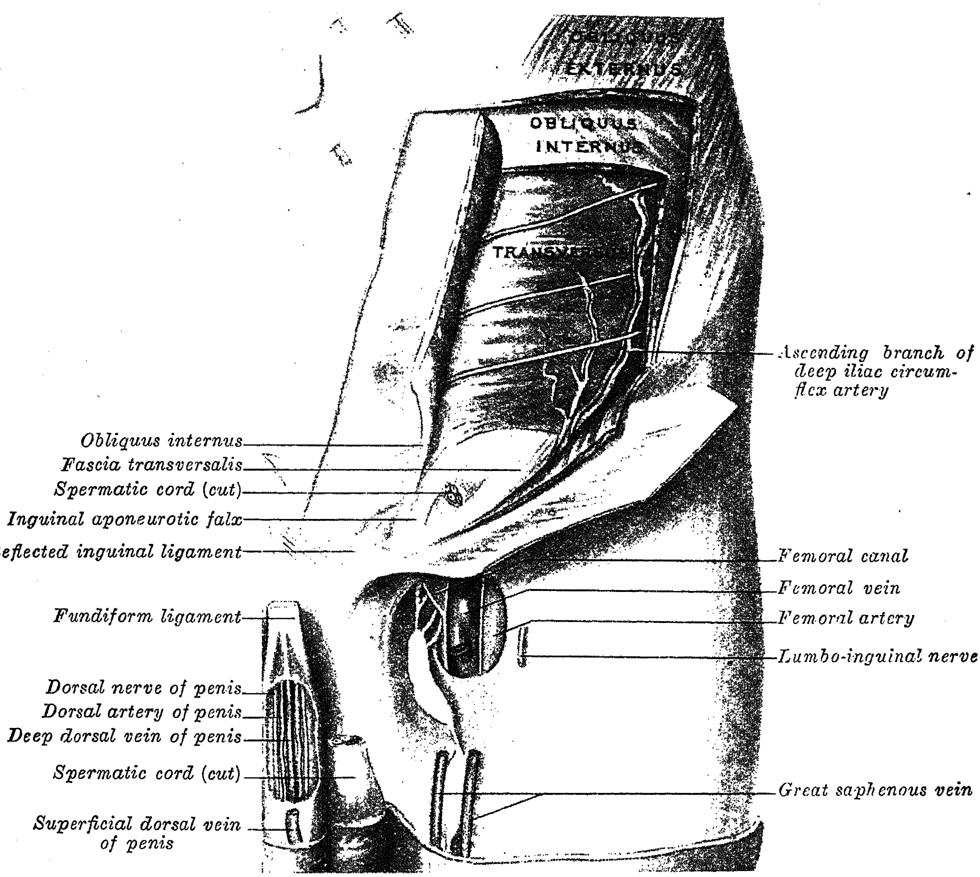
The *inguinal aponeurotic falx*, or *conjoined tendon* of the Obliquus internus and Transversus (figs. 557, 558), is mainly formed by the lower part of the tendon of the Transversus, and is inserted into the crest of the os pubis and pecten pubis, immediately behind the subcutaneous inguinal ring, serving to protect what would otherwise be a weak point in the abdominal wall. Lateral

to the falx is a ligamentous band connected with the lower margin of the Transversus and extending down to the superior ramus of the os pubis; it is termed the *interfoveolar ligament* (of Hesselbach) (fig. 558), and sometimes contains a few muscular fibres.

Nerve-supply.—The Transversus abdominis is supplied by the anterior divisions of the lower thoracic and first lumbar nerves.

Actions.—The Transversi abdominis almost completely encircle the abdominal cavity; in action they compress the abdominal contents.

FIG. 557.—A dissection of the regions shown in fig. 552, but with portions of the Obliqui externus et internus removed.



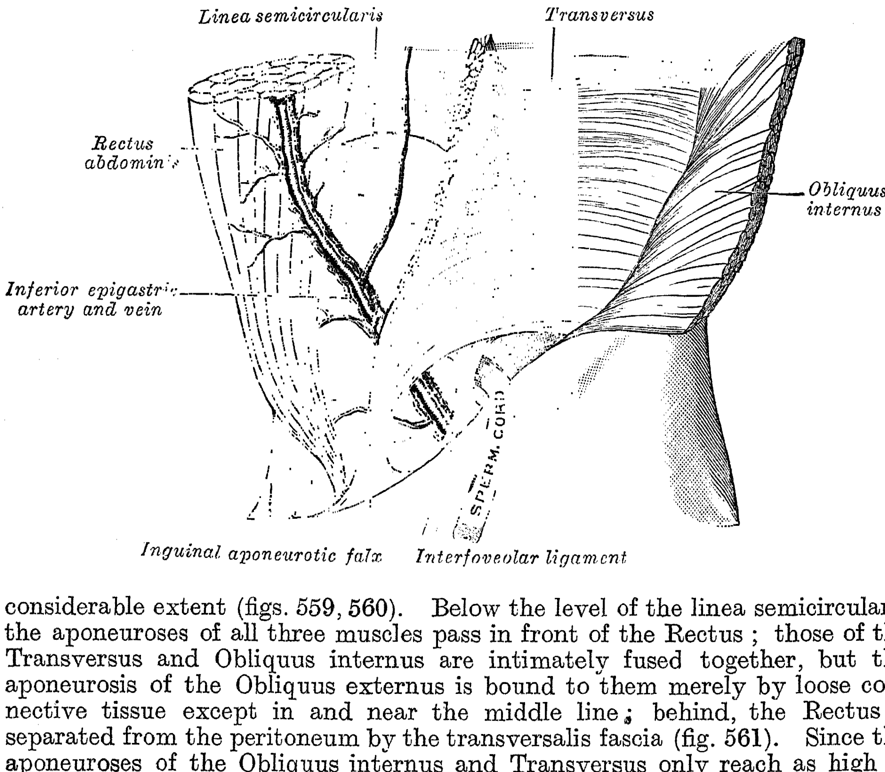
The **Rectus abdominis** (fig. 559) is a long flat muscle, broader above than below, which extends along the whole length of the front of the abdomen, and is separated from its fellow of the opposite side by the linea alba. It arises by two tendons; the lateral and larger is attached to the crest of the os pubis, the medial interlaces with its fellow of the opposite side and is connected with the ligamentous fibres covering the front of the symphysis pubis. The muscle is inserted by three slips of unequal size into the cartilages of the fifth, sixth, and seventh ribs; some fibres of the upper slip are usually inserted into the anterior extremity of the fifth rib; some are occasionally connected with the costoxiphoid ligaments and the side of the xiphoid process.

The Rectus is crossed by three fibrous bands, named *tendinous inscriptions*; one is usually situated opposite the umbilicus, the second opposite the free end of the xiphoid process, and the third about midway between the xiphoid process and the umbilicus. These inscriptions pass transversely or obliquely across the muscle in a zigzag course; they rarely extend completely through its substance and may pass only halfway across it; they are intimately

adherent to the anterior lamina of the sheath of the muscle. Sometimes one or two additional but incomplete inscriptions are present below the umbilicus.

The Rectus abdominus is enclosed in a sheath (figs. 554, 559, 560) formed by the aponeuroses of the Obliqui and Transversus, which are arranged as follows: At the lateral margin of the Rectus, the aponeurosis of the Obliquus internus divides into two lamellæ, one of which passes in front of the Rectus, blending with the aponeurosis of the Obliquus externus, the other, behind it, blending with the aponeurosis of the Transversus, and these, joining again at the medial border of the Rectus, are inserted into the linea alba. This arrangement of the aponeuroses exists from the costal margin to midway between the umbilicus and symphysis pubis, where the posterior wall of the sheath ends in a thin curved margin, the *linea semicircularis* (fig. 559), the concavity of which is directed downwards. In the upper part of the sheath muscular fibres of the Transversus extend into its posterior wall, and not infrequently do so to a

Fig. 558.—The interfoveolar ligament. Anterior aspect. (Modified from Braune.)



considerable extent (figs. 559, 560). Below the level of the linea semicircularis the aponeuroses of all three muscles pass in front of the Rectus; those of the Transversus and Obliquus internus are intimately fused together, but the aponeurosis of the Obliquus externus is bound to them merely by loose connective tissue except in and near the middle line; behind, the Rectus is separated from the peritoneum by the transversalis fascia (fig. 561). Since the aponeuroses of the Obliquus internus and Transversus only reach as high as the costal margin, it follows that above this level the sheath of the Rectus is deficient posteriorly, the muscle resting directly on the cartilages of the ribs; the front of this part of the Rectus is covered merely by the tendon of the Obliquus externus.

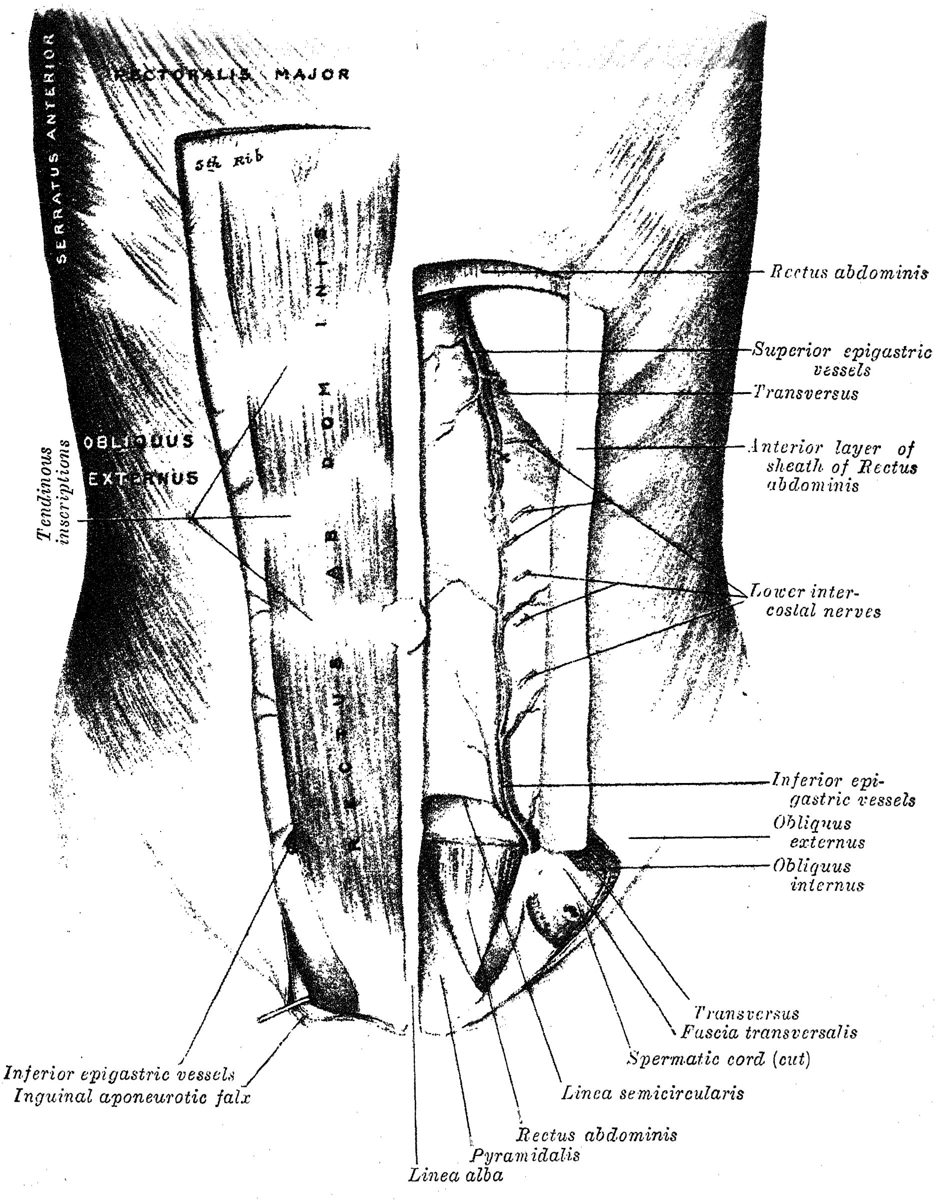
Nerve-supply.—The Rectus abdominis is supplied by the anterior divisions of the lower thoracic nerves.

Actions.—The Rectus abdominis acting from above elevates the front of the pelvis; acting from below it depresses the thorax, and in continued action flexes the vertebral column. The two muscles are also powerful compressors of the abdominal viscera.

Applied Anatomy.—In suturing incisions through the upper part of the sheath of the Rectus abdominis it is necessary to suture the Transversus abdominis where it enters into the formation of the posterior wall of the sheath. The fibres of Transversus abdominis being very pale, fine, and sometimes covered with a thin layer of fat, are liable to be overlooked.

The **Pyramidalis** (fig. 559) is a triangular muscle, placed at the lower part of the abdomen, in front of the Rectus abdominis and within the sheath of that muscle. It arises by tendinous fibres from the front of the os pubis and from the ligamentous fibres in front of the symphysis; the fleshy portion of the muscle passes upwards, diminishing in size as it ascends, and ends in a pointed

FIG. 559.—The right Rectus abdominis and the left Pyramidalis. The greater part of the left Rectus abdominis has been removed to show the superior and inferior epigastric vessels.



extremity which is inserted into the linea alba midway between the umbilicus and os pubis, but may extend to a higher level. This muscle may be larger on one side than on the other, or may be wanting on one or both sides.

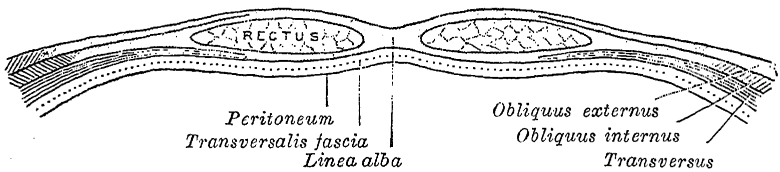
Besides the Rectus and Pyramidalis, the sheath of the Rectus contains the superior and inferior epigastric arteries, and the terminal portions of the lower intercostal nerves.

Nerve-supply.—The Pyramidalis is supplied by the twelfth thoracic nerve.

Action.—The Pyramidalis is a tensor of the linea alba.

The **linea alba** (fig. 559) is a tendinous band in the middle line of the abdomen, stretching between the xiphoid process and the symphysis pubis. It is placed between the medial borders of the Recti, and is formed by the blending of the aponeuroses of the Obliqui and Transversi. It is narrow below, corresponding to the linear interval existing between the Recti; but broader above, where these muscles diverge from one another. Its lower end has a double attachment—its superficial fibres passing in front of the medial heads of the Recti to the symphysis pubis, while its deeper fibres form a triangular lamella, attached behind the Recti to the posterior surface of the crest of the os pubis, and named the *adminiculum lineæ albæ*. The linea alba presents apertures for the passage of vessels and nerves; the umbilicus, which in the fœtus exists as an aperture and transmits the umbilical vessels, is closed a few days after birth.

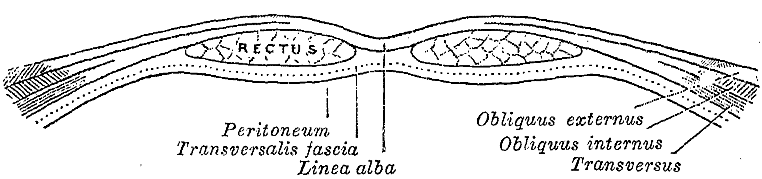
Fig. 560.—A transverse section through the anterior abdominal wall, above the umbilicus. Diagrammatic.



The **lineæ semilunares** are two curved tendinous lines corresponding with the lateral borders of the Recti; each extends from the cartilage of the ninth rib to the pubic tubercle, and marks the line along which the aponeurosis of the Obliquus internus splits to enclose the Rectus abdominis.

The **transversalis fascia** is a thin membrane which lies between the inner surface of the Transversus muscle and the extraperitoneal fat. It forms part of the general layer of fascia lining the abdominal parietes, and is continuous with the iliac and pelvic fasciæ. In the inguinal region it is thick and dense in structure, and is joined by fibres from the aponeurosis of the Transversus, but it becomes thin as it ascends to the Diaphragm, and blends with the fascia covering the under surface of this muscle. Behind, it is lost in the fat which covers the posterior surfaces of the kidneys. Below, it has the following attachments: posteriorly, to the whole length of the iliac crest,

Fig. 561.—A transverse section through the anterior abdominal wall, below the linea semicircularis. Diagrammatic.



between the origins of the Transversus and Iliacus; between the anterior superior iliac spine and the femoral vessels it is connected to the posterior margin of the inguinal ligament, and is there continuous with the iliac fascia. Medial to the femoral vessels it is thin and is fixed to the pecten pubis, behind the inguinal aponeurotic falx, with which it is united; it descends in front of the femoral vessels to form the anterior wall of the femoral sheath. The spermatic cord in the male, and the round ligament of the uterus in the female, pass through the transversalis fascia at a spot called the *abdominal inguinal ring*. This opening is not visible externally since the transversalis fascia is prolonged on these structures as the infundibuliform fascia.

The **abdominal inguinal ring** (internal abdominal ring) is situated in the transversalis fascia, midway between the anterior superior iliac spine and

the symphysis pubis, and 1·25 cm. above the inguinal ligament. It is of an oval form, the long axis of the oval being vertical; it varies in size in different subjects, and is much larger in the male than in the female. It is bounded above by the arched lower margin of the Transversus, and medially by the inferior epigastric vessels. It transmits the spermatic cord in the male and the round ligament of the uterus in the female. From its circumference a thin funnel-shaped membrane, the *infundibuliform fascia*, is continued as a covering on the spermatic cord and testis.

The **inguinal canal** contains the spermatic cord and the ilio-inguinal nerve in the male, and the round ligament of the uterus and the ilio-inguinal nerve in the female. It is an oblique canal about 4 cm. long, slanting downwards and medialwards, and placed parallel with and a little above the inguinal ligament; it extends from the abdominal inguinal ring to the subcutaneous inguinal ring. It is bounded *in front* by the integument, superficial fascia, and aponeurosis of the Obliquus externus throughout its whole length, and by the Obliquus internus in its lateral one-third; *behind* by the reflected inguinal ligament, the inguinal aponeurotic falx, the transversalis fascia, the extraperitoneal connective tissue, and the peritoneum; *above* by the arched fibres of the Obliquus internus and Transversus abdominis; *below* by the union of the transversalis fascia with the inguinal ligament, and at its medial end by the lacunar ligament.

The **extraperitoneal connective tissue.**—Between the inner surface of the general layer of the fascia which lines the interior of the abdominal and pelvic cavities, and the peritoneum, there is a considerable amount of connective tissue, termed the *extraperitoneal or subperitoneal connective tissue.* For descriptive purposes it may be divided into a parietal and a visceral portion.

The *parietal* portion lines the cavity, and varies in quantity in different situations. It is especially abundant on the posterior wall of the abdomen, and particularly around the kidneys, where it contains much fat. It is scanty on the anterolateral wall of the abdomen, except in the pubic region and above the iliac crest; there is a considerable amount in the pelvis.

The *visceral* portion follows the course of the branches of the abdominal aorta between the layers of the mesenteries and other folds of peritoneum which connect the viscera to the abdominal and pelvic walls.

2. The Posterior Muscles of the Abdomen

Psoas major.	Iliacus.
Psoas minor.	Quadratus lumborum.

The Psoas major, the Psoas minor, and the Iliacus, with the fasciæ covering them are described with the muscles of the lower extremity (p. 530).

The **fascia covering the Quadratus lumborum** is a thin layer attached, medially, to the bases of the transverse processes of the lumbar vertebræ; below, to the iliolumbar ligament; above, to the apex and lower border of the last rib. The upper margin of this fascia, which extends from the transverse process of the first lumbar vertebra to the apex and lower border of the last rib constitutes the lateral lumbocostal arch (p. 465). Laterally, the fascia blends with the layer of the lumbodorsal fascia, which intervenes between the Quadratus lumborum and the Sacrospinalis.

The **Quadratus lumborum** (fig. 546, p. 459) is irregularly quadrilateral in shape, and broader below than above. It arises by aponeurotic fibres from the iliolumbar ligament and the adjacent portion of the iliac crest for about 5 cm., and is inserted into the lower border of the last rib for about one-half its length, and by four small tendons into the apices of the transverse processes of the upper four lumbar vertebræ. Occasionally a second portion of this muscle is found in front of the preceding; it arises from the upper borders of the transverse processes of the lower three or four lumbar vertebræ, and is inserted into the lower margin of the last rib.

In front of the Quadratus lumborum are the colon, the kidney, the Psoas major et minor, and the Diaphragm; between the fascia and the muscle are the twelfth thoracic, iliohypogastric, and ilio-inguinal nerves.

Nerve-supply.—The Quadratus lumborum is supplied by the anterior divisions of the twelfth thoracic and upper three or four lumbar nerves.

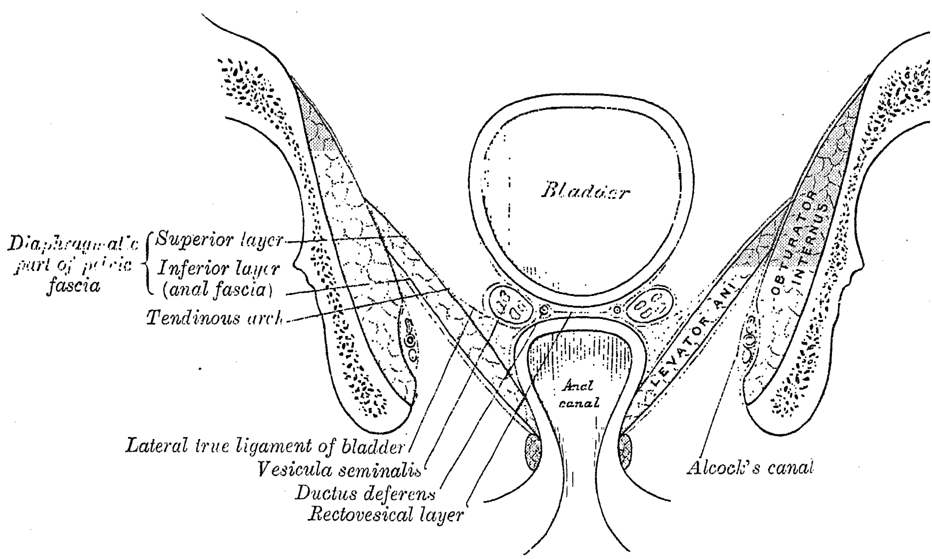
Actions.—The Quadratus lumborum draws down the last rib, and acts as a muscle of inspiration by helping to fix the origin of the Diaphragm. If the thorax and vertebral column are fixed, it may act upon the pelvis, raising it towards its own side when only one muscle is put in action ; and when both muscles act together, either from below or above, they flex the trunk.

V. The Muscles of the Pelvis

Obturator internus.	Levator ani.
Piriformis.	Coccygeus.

The muscles within the pelvis may be divided into two groups : (1) the Piriformis and the Obturator internus, which are described with the muscles of the lower extremity (pp. 543, 544) ; (2) the Levator ani and the Coccygeus, which together form the *pelvic diaphragm* and are associated with the pelvic viscera. The classification of the two groups under a common heading is convenient in connexion with the fasciæ investing the muscles. These fasciæ are closely related to one another and to the deep fascia of the perinæum, and in addition are connected with the fascial coverings of the pelvic viscera ; it is customary therefore to describe them together under the term *pelvic fascia.*

Fig. 562.—A coronal section through the pelvis, showing the arrangement of the fasciæ. Posterior aspect. Diagrammatic.



Pelvic fascia.—The fascia of the pelvis may be resolved into : (A) the fascial sheaths of the Obturator internus, Piriformis, and pelvic diaphragm ; (B) the fascial sheaths of the pelvic viscera (see section on Splanchnology).

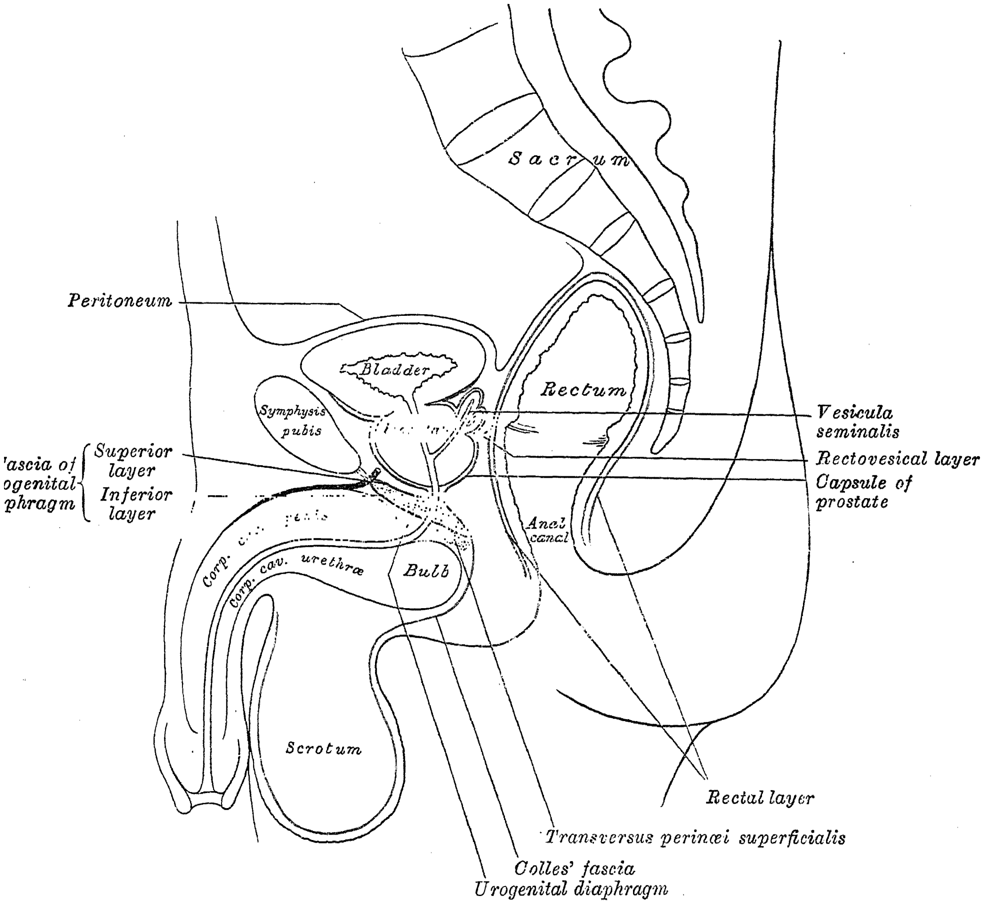
The *fascia of the Obturator internus* covers the pelvic surface of, and is attached round the margin of the origin of, the muscle. Above, it is connected to the posterior part of the arcuate line, and is there continuous with the iliac fascia. In front of this, as it follows the line of origin of the Obturator internus, it gradually separates from the iliac fascia, and the continuity between the two is retained only through the periosteum. It arches beneath the obturator vessels and nerve, completing the obturator canal, and at the front of the pelvis is attached to the back of the superior ramus of the os pubis. The lower part of the obturator fascia forms the lateral wall of the ischiorectal fossa, and is attached inferiorly to the falciform process of the sacrotuberous ligament and

to the pubic arch; at the pubic arch it is continuous with the superior fascia of the urogenital diaphragm. Behind, it is prolonged into the glutæal region.

The internal pudendal vessels and pudendal nerve are placed in the lateral wall of the ischiorectal fossa, and are enclosed in a special sheath of the fascia, named *Alcock's canal.*

The *fascia of the Piriformis* is very thin and is attached to the front of the sacrum around the margins of the anterior sacral foramina; it is prolonged on the muscle into the glutæal region. At its sacral attachment it comes into

FIG. 563.—A median sagittal section through the pelvis, showing the arrangement of the fasciæ. Diagrammatic.

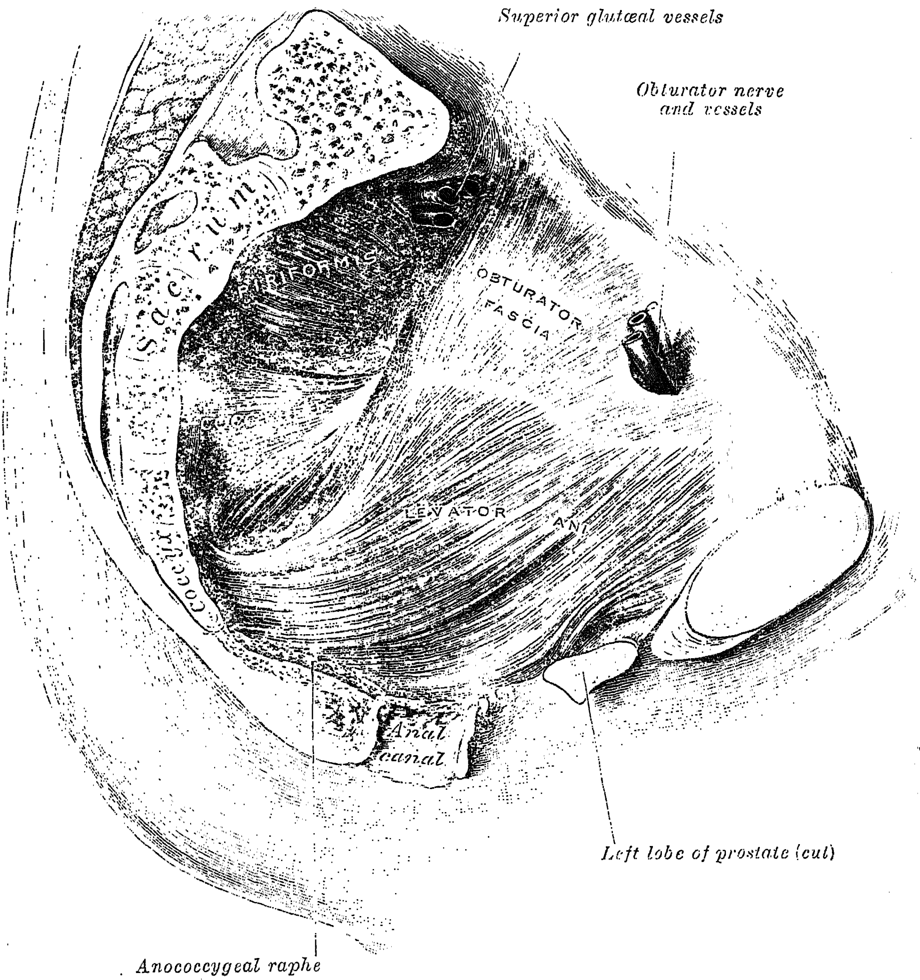


intimate association with and ensheathes the nerves emerging from these foramina; hence the sacral nerves are frequently described as lying behind the fascia. The internal iliac vessels and their branches, on the other hand, lie in the subperitoneal tissue in front of the fascia, and the branches of these vessels to the glutæal region emerge in special sheaths of this tissue, above and below the Piriformis muscle.

The *diaphragmatic part of the pelvic fascia* (fig. 562) covers both surfaces of the Levatores ani. That on the inferior surface of the muscle is very thin, and known as the *anal fascia*; it forms the medial wall of the ischiorectal fossa, and is attached above to the obturator fascia along the line of origin of the Levator ani; it is continuous below with the superior fascia of the urogenital diaphragm, and with the fascia on the Sphincter ani externus. The layer covering the upper surface of the Levator ani follows, above, the line of origin of the muscle, and is therefore somewhat variable. In front it is attached to

the back of the symphysis pubis about 2 cm. above its lower border, and can be traced lateralwards across the back of the superior ramus of the os pubis for a distance of 1·25 cm., when it reaches the obturator fascia. It is attached to this fascia along a line which pursues a somewhat irregular course to the spine of the ischium. The irregularity of this line is explained by the fact that the origin of the Levator ani, which in lower mammals is from the pelvic brim,

FIG. 564.—The left Levator ani. Pelvic aspect.



is in man lower down, on the obturator fascia, but tendinous fibres of origin of the muscle are often found extending up towards, and in some cases reaching, the pelvic brim, and on these the fascia is carried. The lower margin of the fascia covering the upper surface of the pelvic diaphragm is attached along the line of insertion of the Levator ani. The fascia covering that part of the Obturator internus which lies above the origin of the Levator ani is therefore a composite structure and includes, (*a*) the obturator fascia, (*b*) the fascia of the Levator ani, and (*c*) the degenerated fibres of origin of the Levator ani.

At the level of a line extending from the lower part of the symphysis pubis to the spine of the ischium is a thickened whitish band in this upper layer of the diaphragmatic part of the pelvic fascia. It is termed the *tendinous arch* or *white line* of the pelvic fascia, and marks the line of attachment of the lateral true ligament of the urinary bladder. Anteriorly the fascia forms two thickened bands, the *puboprostatic ligaments*, one on either side of the middle line.

The **Levator ani** (fig. 564) is a broad, thin muscle; it is attached to the inner surface of the side of the lesser pelvis, and unites with its fellow of the opposite side to form the greater part of the floor of the pelvic cavity. It arises, in front, from the pelvic surface of the superior ramus of the os pubis lateral to the symphysis; behind, from the inner surface of the spine of the ischium; and between these two points, from the obturator fascia. Posteriorly this origin from the obturator fascia corresponds, more or less closely, with the tendinous arch or white line of the pelvic fascia, but in front, the muscle arises from the fascia at a varying distance above the arch, in some cases reaching nearly as high as the canal for the obturator vessels and nerve. The fibres pass downwards and backwards to the middle line of the floor of the pelvis; the posterior fibres are inserted into the side of the last two segments of the coccyx and into a median fibrous raphe (*anococcygeal raphe*), which extends between the coccyx and the margin of the anus. The middle fibres are inserted into the side of the anal canal, blending with those of the Sphincter ani muscles; the anterior fibres descend upon the side of the prostate to unite beneath it with the muscle of the opposite side, joining with the fibres of the Sphincter ani externus and Transversus perinæi superficialis at the central tendinous point of the perinæum.

The anterior portion is occasionally separated from the rest of the muscle by connective tissue. From this circumstance, as well as from its peculiar relation with the prostate, which it supports as in a sling, it has been described as a distinct muscle, under the name of *Levator prostatæ*. In the female the anterior fibres of the Levator ani descend upon the side of the vagina.

The Levator ani may be divided into Iliococcygeus and Pubococcygeus.

The *Iliococcygeus* arises from the ischial spine and from the posterior part of the tendinous arch of the pelvic fascia, and is attached to the coccyx and anococcygeal raphe; it is usually thin, and may fail entirely or be largely replaced by fibrous tissue. An accessory slip at its posterior part is sometimes named the *Iliosacralis*. The *Pubococcygeus* arises from the back of the os pubis and from the anterior part of the obturator fascia, and is directed backwards almost horizontally along the side of the anal canal. Between the coccyx and the anal canal the Pubococcygei come together and form a thick, fibromuscular layer lying on the raphe formed by the Iliococcygei. The fibres which form a sling for the rectum are named the *Puborectalis* or *Sphincter recti*; they rise from the lower part of the symphysis pubis, and from the superior fascia of the urogenital diaphragm; they meet with the corresponding fibres of the opposite side around the lower part of the rectum, and form for it a strong sling.

Symington * suggests that the Pubococcygeus should be named *Pubo-analis*, as it is doubtful if any of its fibres reach the coccyx.

Relations.—The *upper or pelvic surface* of the Levator ani is in relation with the diaphragmatic part of the pelvic fascia which separates it from the bladder, prostate, rectum, and peritoneum. Its *lower or perinæal surface* forms the medial boundary of the ischiorectal fossa, and is covered by the inferior layer of the diaphragmatic part of the pelvic fascia (*anal fascia*). Its *posterior border* is free and separated from the Coccygeus muscle by areolar tissue. Its *anterior border* is separated from the muscle of the opposite side by a triangular space, through which the urethra, and in the female the urethra and vagina, pass from the pelvis.

Nerve-supply.—The Levator ani is supplied by a branch from the fourth sacral nerve and by a branch which arises either from the perinæal, or from the inferior hæmorrhoidal, division of the pudendal nerve.

Actions.—The Levatores ani constrict the lower end of the rectum and vagina. Together with the Coccygei they form a muscular diaphragm which supports the pelvic viscera.

The **Coccygeus** (fig. 564) is situated behind the Levator ani. It is a triangular plane of muscular and tendinous fibres, arising by its apex from the spine of the ischium and from the sacrospinous ligament, and inserted by its base into the margin of the coccyx and into the side of the lowest piece of the sacrum. It assists the Levator ani and Piriformis in closing the posterior part of the outlet of the pelvis.

Nerve-supply.—The Coccygeus is supplied by a branch from the fourth and fifth sacral nerves.

Actions.—The Coccygei pull forward and support the coccyx, after it has been pressed backwards during defæcation or parturition.

* *Journal of Anatomy and Physiology*, vol. xlvi.

Applied Anatomy.—Injury to the muscles forming the pelvic diaphragm occurs not infrequently during parturition. Where the damage is considerable or in cases where the muscles are weak the Levatores ani fail to act as efficient supports and prolapse of the uterus results; in severe cases the ovaries, bladder and rectum may also prolapse.

VI. The Muscles of the Perinæum

The perinæum corresponds to the outlet of the pelvis. Its deep boundaries are—in front, the pubic arch and the arcuate pubic ligament; behind, the tip of the coccyx; and on either side the inferior rami of the os pubis and ischium, the ischial tuberosity, and the sacrotuberous ligament. The space is somewhat lozenge-shaped and is limited on the surface of the body by the scrotum in front, by the buttocks behind, and by the medial sides of the thighs laterally. A line drawn transversely in front of the ischial tuberosities divides the space into two portions. The posterior contains the termination of the anal canal, and is known as the *anal region*; the anterior contains the external urogenital organs, and is termed the *urogenital region.*

The muscles of the perinæum may therefore be divided into two groups:

1. Those of the anal region.
2. Those of the urogenital region: A, In the male; B, In the female.

1. The Muscles of the Anal Region

Corrugator cutis ani. Sphincter ani externus. Sphincter ani internus.

The **superficial fascia** is very thick, areolar in texture, and contains much fat in its meshes. On either side a pad of fatty tissue extends deeply between the Levator ani and Obturator internus into a space known as the *ischiorectal fossa.*

The **deep fascia** forms the lining of the ischiorectal fossa; it comprises the anal fascia, and the portion of obturator fascia below the origin of Levator ani.

Ischiorectal fossa.—The fossa is somewhat prismoid in shape, with its base directed to the surface of the perinæum, and its apex at the line of meeting of the obturator and anal fasciæ. It is bounded medially by the Sphincter ani externus and the anal fascia; laterally, by the tuberosity of the ischium and the obturator fascia; anteriorly, by the fascia of Colles covering the Transversus perinæi superficialis, and by the fascia of the urogenital diaphragm; posteriorly, by the Glutæus maximus and the sacrotuberous ligament. Crossing the space transversely are the inferior hæmorrhoidal vessels and nerves; at the posterior part are the perinæal and perforating cutaneous branches of the pudendal plexus; while from the anterior part the posterior scrotal (or labial) vessels and nerves emerge. The internal pudendal vessels and pudendal nerve lie on the lateral wall of the fossa, in Alcock's canal (p. 483). The fossa is filled with fatty tissue, across which numerous fibrous bands extend.

Applied Anatomy.—Abscess in the ischiorectal fossa commonly occurs; it may bulge at the side of the anus, at the border of Glutæus maximus, or against the rectal wall. There is great pain on defæcation. On examining the bowel, fullness on the side of the abscess may be detected. If left to itself the pus will find exit through the skin, or into the anal canal between the two Sphincters; and the condition will degenerate into one of the varieties of fistula, owing to the Sphincter ani externus closing the outlet of the abscess, and so causing the pus to track and burrow widely into the soft fat in the fossa, and also in the subcutaneous tissues. To open an ischiorectal abscess an incision should be made tangential to the anus over the region of the ischiorectal fossa, and should then be converted into a T, by making a second incision laterally at right angles to it, so that the wound may be kept open and may heal up from the bottom. Frequently, however, in spite of care, a fistula ensues which requires division of the Sphincter ani externus for its cure.

The **Corrugator cutis ani.**—Around the anus is a thin stratum of involuntary muscular fibres which radiate from the anal orifice. Medially the fibres fade off into the submucous tissue; laterally they blend with the true skin. When the muscle contracts the skin around the anus is raised into ridges.

The **Sphincter ani externus** (figs. 565, 567) is a flat sheet of muscular fibres, elliptical in shape and intimately adherent to the skin surrounding the anus. It measures from 8 to 10 cm. in length and is about 2·5 cm. in width opposite the anus. It consists of two portions, superficial and deep. The *superficial portion* constitutes the chief part of the muscle, and arises from a narrow tendinous band, the *anococcygeal raphe,* which stretches from the tip of the coccyx to the posterior margin of the anus; it forms two flattened sheets of muscular tissue, which encircle the anus and meet in front to be inserted into the central tendinous point of the perinæum, joining with the Transversus perinæi superficialis, the Levator ani, and the Bulbocavernosus. The *deep portion* forms a complete sphincter to the anal canal. Its fibres surround the canal, closely applied to the Sphincter ani internus, and in front blend with the other muscles at the central point of the perinæum. In a considerable proportion of cases the fibres decussate in front of the anus, and are continuous with the Transversi perinæi superficiales. Posteriorly, they are not attached to the coccyx, but are continuous with those of the opposite side behind the anal canal. The upper edge of the muscle is ill-defined, since fibres are given off from it to join the Levator ani.

Nerve-supply.—The Sphincter ani externus is supplied by a branch from the fourth sacral nerve and by twigs from the inferior hæmorrhoidal branch of the pudendal nerve.

Actions.—The action of the Sphincter ani externus is peculiar. 1. It is normally in a state of tonic contraction, and having no antagonistic muscle it keeps the anal canal and orifice closed. 2. It can be put into a condition of greater contraction under the influence of the will, so as more firmly to occlude the anal aperture. 3. Taking its fixed point at the coccyx, it helps to fix the central point of the perinæum.

The **Sphincter ani internus** is a muscular ring which surrounds about 2·5 cm. of the anal canal; its inferior border is in contact with, but distinct from, the Sphincter ani externus. It is about 5 mm. thick, and is formed by an aggregation of the involuntary circular fibres of the intestine. Its lower border is about 6 mm. from the orifice of the anus.

Actions.—Its action is entirely involuntary. It helps the Sphincter ani externus to occlude the anal aperture.

2. a. The Muscles of the Urogenital Region in the Male (fig. 565)

Transversus perinæi superficialis.	Ischiocavernosus.
Bulbocavernosus.	Transversus perinæi profundus.

Sphincter urethræ membranaceæ.

The **superficial fascia** of this region consists of two layers, superficial and deep.

The *superficial layer* is thick, loose, areolar in texture, and contains a variable amount of fat in its meshes. In front, it is continuous with the dartos tunic of the scrotum; behind, with the subcutaneous areolar tissue surrounding the anus; and, on either side, with the same fascia on the medial sides of the thighs. In the middle line, it is adherent to the skin and to the deep layer of the superficial fascia.

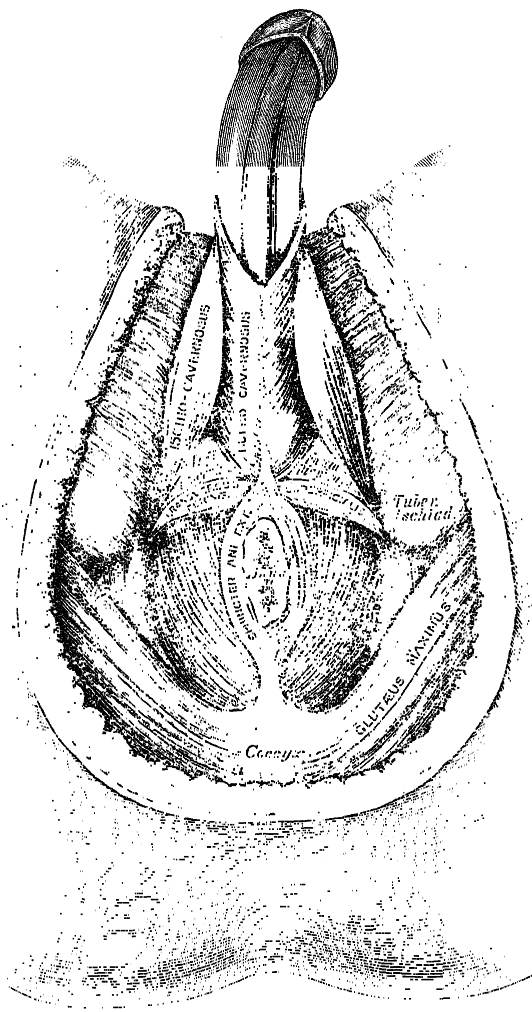
The *deep layer of superficial fascia* (fascia of Colles) (fig. 563) is thin, aponeurotic in structure, and of considerable strength, serving to bind down the muscles of the root of the penis. It is continuous, in front, with the dartos tunic, the deep fascia of the penis, the fascia of the spermatic cord, and Scarpa's fascia upon the anterior wall of the abdomen; on either side it is attached to the margins of the rami of the os pubis and ischium, lateral to the crus penis and as far back as the tuberosity of the ischium; posteriorly, it curves round the Transversi perinæi superficiales to join the posterior margin of the inferior fascia of the urogenital diaphragm. In the middle line, it is connected with the superficial fascia and with the median septum of the Bulbocavernosus. At its posterior part this fascia sends upwards from its deep surface a median septum, which incompletely divides the posterior portion of the subjacent space.

The central tendinous point of the perinæum.—This is a fibrous point in the middle line of the perinæum about 1·25 cm. in front of the anus, and

close to the urethral bulb. Towards this point six muscles converge and are attached: viz. the Sphincter ani externus, the Bulbocavernosus, the two Transversi perinæi superficiales, and the anterior fibres of the two Levatores ani.

The **Transversus perinæi superficialis** is a narrow muscular slip, which passes more or less transversely across the perinæal space in front of the anus. It is often feebly developed, and is sometimes absent. It arises by tendinous

Fig. 565.—The muscles of the male perinæum.



fibres from the medial and anterior part of the tuberosity of the ischium, and, running medialwards, is inserted into the central tendinous point of the perinæum, joining in this situation with the muscle of the opposite side, with the Sphincter ani externus behind, and with the Bulbocavernosus in front. In some cases, the fibres of the deeper layer of the Sphincter ani externus decussate in front of the anus and are continued into this muscle. Occasionally it gives off fibres which join with the Bulbocavernosus of the same side.

Nerve-supply.—The Transversus perinæi superficialis is supplied by the perinæal branch of the pudendal nerve.

Action.—The simultaneous contraction of the two Transversi perinæi superficiales serves to fix the central tendinous point of the perinæum.

The **Bulbocavernosus** (Ejaculator urinæ) is placed in the middle line of the perinæum, in front of the anus, and consists of two symmetrical parts, united by a median tendinous raphe. It arises from this median raphe and the central tendinous point of the perinæum. Its fibres diverge like the barbs of a quill-pen; the most posterior form a thin layer, which is lost on the inferior fascia of the urogenital diaphragm; the middle fibres encircle the bulb and adjacent parts of the corpus cavernosum urethræ, and are inserted into a strong aponeurosis on the upper part of the corpus cavernosum urethræ; the anterior fibres spread out over the side of the corpus cavernosum penis, to be inserted partly into that body, anterior to the Ischiocavernosus, and partly into a tendinous expansion which covers the dorsal vessels of the penis.

Nerve-supply.—The Bulbocavernosus is supplied by the perinæal branch of the pudendal nerve.

Actions.—The Bulbocavernosus serves to empty the canal of the urethra, after the bladder has expelled its contents; during the greater part of the act of micturition its fibres are relaxed, and they only come into action at the end of the process. The middle fibres are supposed by Krause to assist in the erection of the corpus cavernosum urethræ, by compressing the erectile tissue of the bulb. The anterior fibres, according to Tyrrel, also contribute to the erection of the penis by compressing the deep dorsal vein of the penis, as their tendinous expansion is inserted into, and is continuous with, the fascia of the penis.

The **Ischiocavernosus** (Erector penis) covers the crus penis. It arises by tendinous and fleshy fibres from the inner surface of the tuberosity of the ischium, behind the crus penis; and from the inferior ramus of the ischium on either side of the crus. The muscular fibres end in an aponeurosis which is inserted into the sides and under surface of the crus penis.

Nerve-supply.—The Ischiocavernosus is supplied by the perinæal branch of the pudendal nerve.

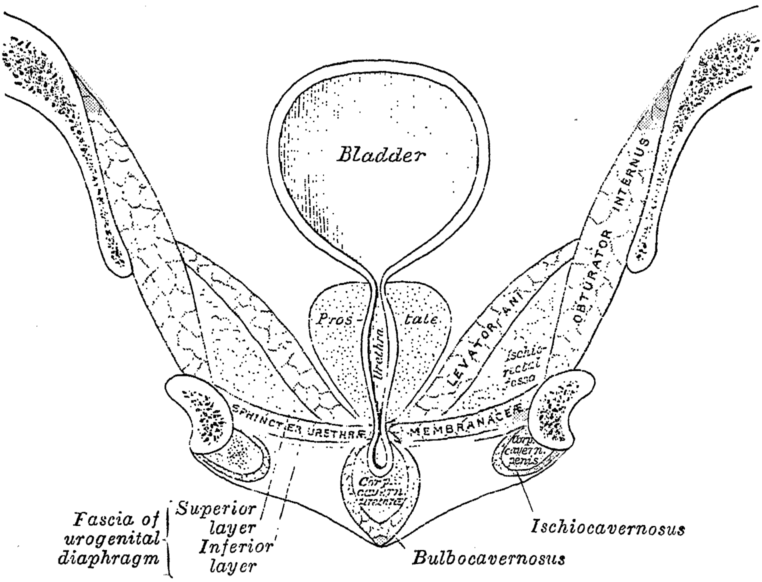
Action.—The Ischiocavernosus compresses the crus penis, and retards the return of the blood through the veins, and thus serves to maintain the penis erect.

Between the muscles just examined a triangular space exists, bounded medially by the Bulbocavernosus, laterally by the Ischiocavernosus, and behind by the Transversus perinæi superficialis; the floor is formed by the inferior fascia of the urogenital diaphragm. Running from behind forwards in the space are the posterior scrotal vessels and nerves, and the perinæal branch of the posterior femoral cutaneous nerve; the transverse perinæal artery courses along its posterior boundary on the Transversus perinæi superficialis.

The **deep fascia** of the urogenital region forms an investment for the Transversus perinæi profundus and the Sphincter urethræ membranaceæ, but within it there are also the deep vessels and nerves of this part, the whole forming a transverse septum which is known as the *urogenital diaphragm*. From its shape this part of the deep fascia is sometimes termed the *triangular ligament*, and it is stretched almost horizontally across the pubic arch, so as to close the anterior part of the pelvic outlet. It consists of two membranous laminæ (fig. 566), which are united at the free edges of the muscles. The stronger and more superficial of these laminæ is named the *inferior fascia of the urogenital diaphragm* (superficial layer of the triangular ligament). Its base, directed backwards, is connected to the central tendinous point of the perinæum and is continuous with the anal fascia, and, behind the Transversus perinæi superficialis, with the deep layer of the superficial fascia. Its lateral margins are attached to the inferior rami of the os pubis and ischium, above the crus penis. Its apex, directed forwards is thickened to form the *transverse ligament of the pelvis*; between this ligament and the arcuate pubic ligament the deep dorsal vein of the penis (or clitoris) enters the pelvis. It is perforated, from 2 to 3 cm. below the symphysis pubis, by the urethra, the aperture for which is circular and about 6 mm. in diameter; by the arteries and nerves to the bulb and the ducts of the bulbo-urethral glands close to the urethra; by the deep arteries of the penis, one on either side close to the pubic arch and about halfway along the attached margin of the fascia; by the dorsal arteries and nerves of the penis near the apex of the fascia. Its base is also perforated by the posterior scrotal vessels and nerves, while between its apex and the arcuate pubic ligament the deep dorsal vein of the penis passes upwards into the pelvis.

If the inferior fascia of the urogenital diaphragm be detached, the following structures will be seen between it and the superior fascia: the membranous portion of the urethra, the Transversus perinæi profundus and Sphincter urethræ membranaceæ, the bulbo-urethral glands and their ducts, the pudendal vessels and dorsal nerves of the penis, the arteries and nerves of the urethral bulb, and a plexus of veins.

FIG. 566.—A coronal section through the anterior part of the pelvis. Anterior aspect. Diagrammatic.



The *superior fascia of the urogenital diaphragm* (deep layer of the triangular ligament) is continuous with the obturator fascia and stretches across the pubic arch. If the obturator fascia be traced medialwards after leaving the Obturator internus muscle, it will be found attached by some of its anterior fibres to the inner margin of the pubic arch, while its posterior fibres pass over this attachment to become continuous with the superior fascia of the urogenital diaphragm. Behind, this layer of the fascia blends with the inferior fascia of the urogenital diaphragm and with the fascia of Colles; in front it is continuous with the fascial sheath of the prostate, and is fused with the inferior fascia.

The **Transversus perinæi profundus** arises from the inferior rami of the ischium and runs to the median line, where it interlaces in a tendinous raphe with its fellow of the opposite side. It lies in the same plane as the Sphincter urethræ membranaceæ; formerly the two muscles were described together as the *Constrictor urethræ*.

Nerve-supply.—The Transversus perinæi profundus is supplied by the perinæal branch of the pudendal nerve.

Action.—The Transversus perinæi profundus is a tensor of the central point of the perinæum.

The **Sphincter urethræ membranaceæ** surrounds the membranous portion of the urethra, and is enclosed in the fascia of the urogenital diaphragm. Its *external* fibres arise from the junction of the inferior rami of the os pubis and ischium, to the extent of 1·25 or 2 cm., and from the neighbouring fasciæ. They arch across the front of the urethra and bulbo-urethral glands, pass round the urethra, and behind it unite with the muscle of the opposite side, by means of a tendinous raphe. Its *innermost* fibres form a continuous circular investment for the membranous urethra.

Nerve-supply.—The Sphincter urethræ membranaceæ is supplied by the perinæal branch of the pudendal nerve.

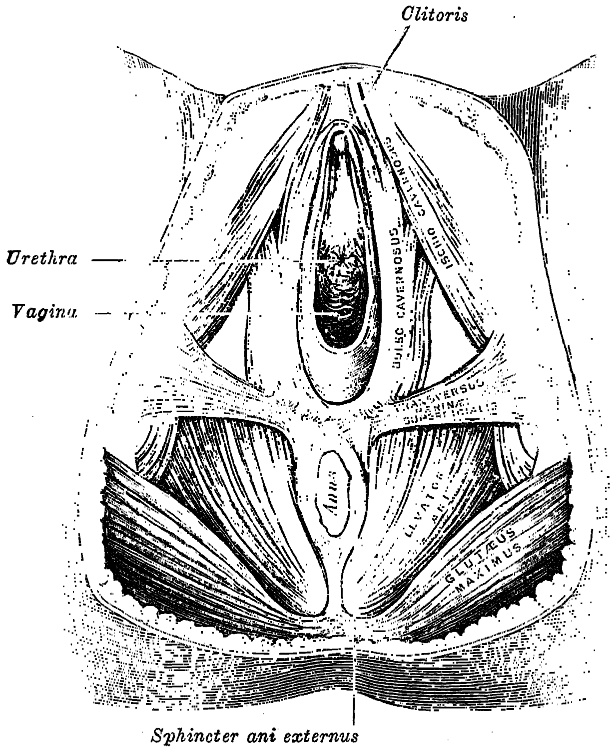
Actions.—The muscles of both sides act together as a sphincter, compressing the membranous portion of the urethra. During micturition they, like the Bulbocavernosus, are relaxed, and only come into action at the end of the process to eject the last drops of urine.

2. B. The Muscles of the Urogenital Region in the Female (fig. 567)

Transversus perinæi superficialis.
Bulbocavernosus.
Ischiocavernosus.
Transversus perinæi profundus.
Sphincter urethræ membranaceæ.

The **Transversus perinæi superficialis** in the female is a narrow muscular slip, which arises by a small tendon from the inner and fore part of the tuberosity of the ischium, and is inserted into the central tendinous point of the perinæum, joining in this situation with the muscle of the opposite side, the Sphincter ani externus behind, and the Bulbocavernosus in front.

FIG. 567.—The muscles of the female perinæum. (Modified from a drawing by Peter Thompson.)



Nerve-supply.—The Transversus perinæi superficialis is supplied by the perinæal branch of the pudendal nerve.

Action.—The simultaneous contraction of the two Transversi perinæi superficiales serves to fix the central tendinous point of the perinæum.

The **Bulbocavernosus** (Sphincter vaginæ) surrounds the orifice of the vagina. It covers the lateral parts of the vestibular bulbs, and is attached posteriorly to the central tendinous point of the perinæum, where it blends with the Sphincter ani externus. Its fibres pass forwards on either side of the vagina, to be inserted into the corpora cavernosa clitoridis, a fasciculus crossing over the body of the clitoris so as to compress the deep dorsal vein.

Nerve-supply.—The Bulbocavernosus is supplied by the perinæal branch of the pudendal nerve.

Actions.—The Bulbocavernosus diminishes the orifice of the vagina. The anterior fibres contribute to the erection of the clitoris by the compression of its deep dorsal vein.

The **Ischiocavernosus** (Erector clitoridis), smaller than the corresponding muscle in the male, covers the unattached surface of the crus clitoridis. It arises by tendinous and fleshy fibres from the inner surface of the tuberosity of the ischium, behind the crus clitoridis; from the surface of the crus; and from the adjacent portion of the ramus of the ischium. The muscular fibres end in an aponeurosis which is inserted into the sides and under surface of the crus clitoridis.

Nerve-supply.—The Ischiocavernosus is supplied by the perinæal branch of the pudendal nerve.

Actions.—The Ischiocavernosus compresses the crus clitoridis and retards the return of blood through the veins, and thus serves to maintain the clitoris erect.

The *fascia of the urogenital diaphragm* in the female is weaker than that in the male, and is divided by the aperture of the vagina, with the external coat of which it blends. As in the male, it consists of two layers; between these are the following structures: a portion of the urethra, the Transversus perinæi profundus and Sphincter urethræ membranaceæ muscles, the greater vestibular glands and their ducts, the internal pudendal vessels, the dorsal nerves of the clitoris, the arteries and nerves of the bulbi vestibuli, and a plexus of veins.

The **Transversus perinæi profundus** arises from the inferior rami of the ischium and runs across to the side of the vagina.

Nerve-supply.—The Transversus perinæi profundus is supplied by the perinæal branch of the pudendal nerve.

Action.—The Transversus perinæi profundus helps to fix the central tendinous point of the perinæum.

The **Sphincter urethræ membranaceæ**, like the corresponding muscle in the male, consists of external and internal fibres. The *external* fibres arise on either side from the margin of the inferior ramus of the os pubis. They are directed across the pubic arch in front of the urethra, and pass round it to blend with the muscular fibres of the opposite side, between the urethra and vagina. The *innermost* fibres encircle the lower end of the urethra.

Nerve-supply.—The Sphincter urethræ membranaceæ is supplied by the perinæal branch of the pudendal nerve.

Actions.—The muscles of the two sides act as a constrictor of the urethra and slightly of the vagina.

THE FASCIÆ AND MUSCLES OF THE UPPER EXTREMITY

The muscles of the upper extremity are divisible into the following groups:

I. Muscles connecting the upper extremity with the vertebral column.
II. Muscles connecting the upper extremity with the anterior and lateral thoracic walls.
III. Muscles of the shoulder.
IV. Muscles of the arm.
V. Muscles of the forearm.
VI. Muscles of the hand.

I. The Muscles connecting the Upper Extremity with the Vertebral Column

Trapezius.
Latissimus dorsi.
Rhomboideus major.
Rhomboideus minor.
Levator scapulæ.

The **superficial fascia** of the back forms a layer of considerable thickness and strength, and contains a quantity of granular fat. It is continuous with the general superficial fascia.

The **deep fascia** is a dense fibrous layer, attached above to the superior nuchal line of the occipital bone; in the middle line it is fixed to the ligamentum nuchæ and supraspinal ligament, and to the spinous processes of all the vertebræ below the seventh cervical; laterally, in the neck it is continuous with the fascia colli; over the shoulder it is attached to the spine of the scapula and to the acromion, and is continued downwards over the Deltoideus to the arm; on the thorax it is continuous with the deep fascia of the axilla and chest, and on the abdomen with that covering the abdominal muscles; below, it is attached to the crest of the ilium.

The **Trapezius** (fig. 568) is a flat, triangular muscle, covering the back of the neck and shoulder. It arises from the medial one-third of the superior nuchal line of the occipital bone, the external occipital protuberance, the ligamentum nuchæ, the spinous process of the seventh cervical, and the spinous processes of all the thoracic vertebræ, and the corresponding portion of the supraspinal ligament. The superior fibres proceed downwards and lateralwards, the inferior upwards and lateralwards, and the middle horizontally; the superior fibres are inserted into the posterior border of the lateral one-third of the clavicle; the middle fibres into the medial margin of the acromion and the superior lip of the posterior border of the spine of the scapula; the inferior fibres converge and end in an aponeurosis, which glides over the smooth triangular surface on the medial end of the spine of the scapula, and is inserted into a tubercle at the apex of this smooth triangular surface. The upper part of the Trapezius is connected to the occipital bone by a thin fibrous lamina, firmly adherent to the skin; the middle part arises by a broad semi-elliptical aponeurosis, which reaches from the sixth cervical to the third thoracic vertebra; the lower part arises by short tendinous fibres. The two Trapezius muscles together resemble a trapezium, or quadrangle; two angles corresponding to the shoulders; a third to the occipital protuberance; and the fourth to the spinous process of the twelfth thoracic vertebra.*

The clavicular insertion of this muscle varies in extent; it sometimes reaches as far as the middle of the clavicle, and occasionally blends with or overlaps the posterior edge of the Sternocleidomastoideus.

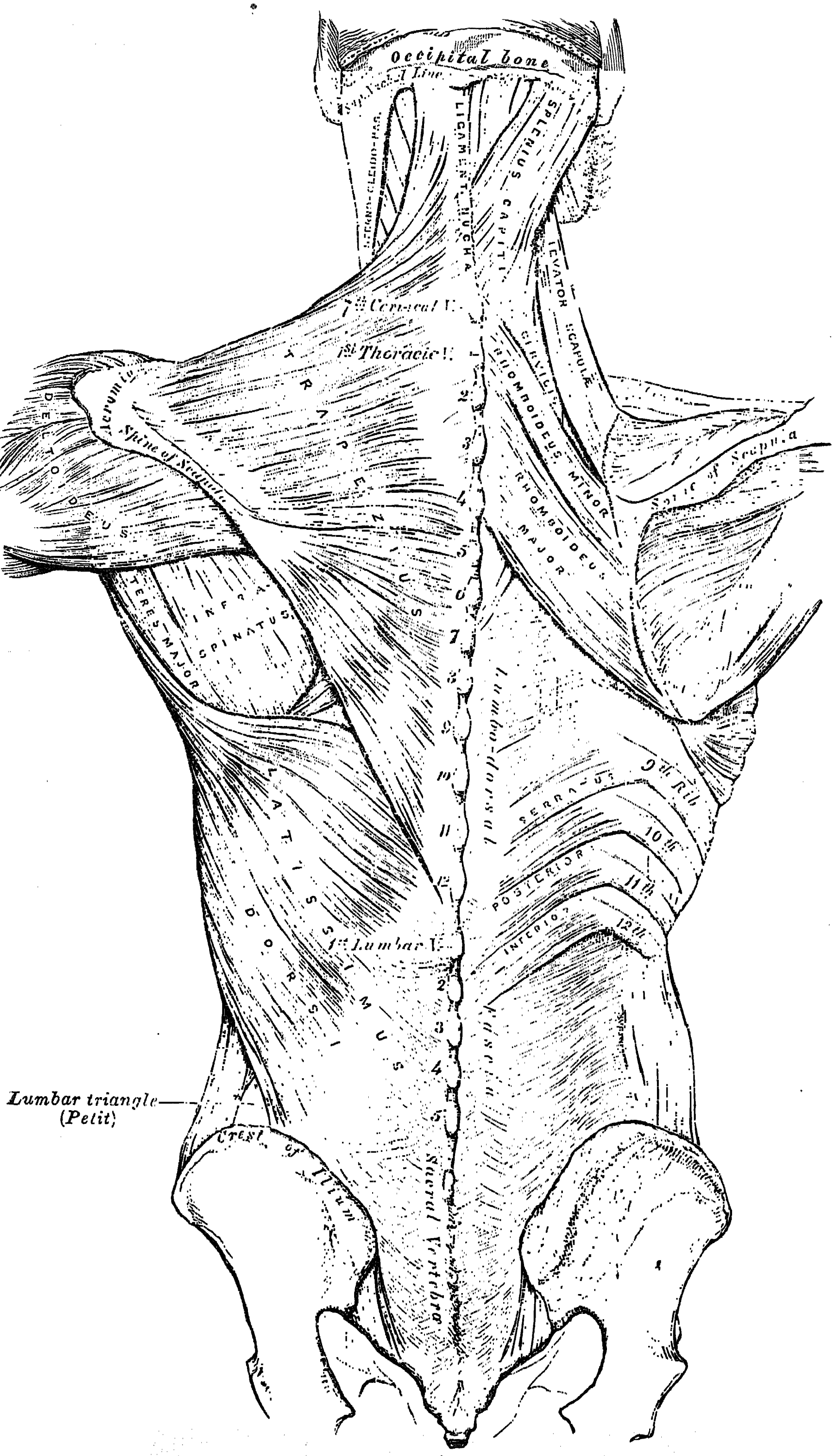
Nerve-supply.—The Trapezius is supplied by the accessory nerve and by branches from the third and fourth cervical nerves.

Actions.—The Trapezius retracts the scapula and braces back the shoulders. If the head be fixed the upper fibres elevate the point of the shoulder; the middle and lower fibres rotate the scapula so as to raise the point of the shoulder. When the shoulder is fixed the Trapezius draws the head backwards and lateralwards.

The **Latissimus dorsi** (fig. 568) is a large triangular, flat muscle, which covers the lumbar region and the lower one-half of the thoracic region; but its fibres converge to a narrow tendon of insertion. It arises by tendinous fibres from the spinous processes of the lower six thoracic vertebræ in front of the Trapezius, and from the posterior layer of the lumbodorsal fascia (p. 457), by which it is attached to the spines of the lumbar and sacral vertebræ, to the supraspinal ligament, and to the posterior part of the crest of the ilium. In addition, it arises by muscular fibres from the external lip of the crest of the ilium lateral to the margin of the Sacrospinalis, and from the three or four lower ribs by fleshy digitations which are interposed between similar processes of the Obliquus abdominis externus (fig. 550). From this extensive origin the fibres pass in different directions, the upper ones horizontally, the middle obliquely upwards, and the lower almost vertically upwards, so as to converge and form a thick fasciculus, the upper part of which crosses, and usually receives a few fibres from, the inferior angle of the scapula. The muscle curves around the lower border of the Teres major, and is twisted upon itself, so that the superior fibres become at first posterior and then inferior, and the ascending fibres at first anterior and then superior. It ends in a quadrilateral tendon, about 7 cm. long, which passes in front of the tendon of the Teres major, and is inserted into the bottom of the intertubercular sulcus of the humerus, giving an expansion to the deep fascia of the arm; its insertion extends higher on the humerus than that of the tendon of the Pectoralis major. The lower border of its tendon is united with that of the Teres major, the

* The two muscles cover the back of the neck and shoulders like a monk's cowl, and therefore the Trapezius is sometimes termed the *Musculus cucullaris*.

Fig. 568.—The muscles connecting the upper extremity with the vertebral column.



surfaces of the two tendons being separated near their insertions by a bursa; another bursa is sometimes interposed between the muscle and the inferior angle of the scapula.

A muscular slip, the *axillary arch*, varying from 7 to 10 cm. in length, and from 5 to 15 mm. in breadth, occasionally springs from the upper edge of the Latissimus dorsi about the middle of the posterior fold of the axilla, and crosses the axilla in front of the axillary vessels and nerves, to join the under surface of the tendon of the Pectoralis major, the Coracobrachialis, or the fascia over the Biceps brachii. This axillary arch crosses the axillary artery, just above the spot usually selected for the application of a ligature, and may mislead the surgeon during the operation. It is present in about seven per cent. of subjects and may be easily recognised by the direction of its fibres.

A fibrous slip usually passes from the lower border of the tendon of the Latissimus dorsi, near its insertion, to the long head of the Triceps brachii. This is occasionally muscular, and is the representative of the *Dorso-epitrochlearis brachii* of apes.

Nerve-supply.—The Latissimus dorsi is supplied by the sixth, seventh and eighth cervical nerves through the thoracodorsal (long subscapular) nerve.

Actions.—The Latissimus dorsi depresses the humerus, draws it backwards, and rotates it inwards. If the arm be fixed, the muscle may elevate the lower ribs in forced inspiration; when both arms are fixed it helps to pull the trunk upwards and forwards as in climbing.

The lower part of the lateral margin of the Latissimus dorsi is separated from the posterior free border of the Obliquus externus abdominis by a small triangular interval, the *lumbar triangle* (of Petit), the base of which is formed by the iliac crest, and its floor by the Obliquus internus abdominis (fig. 568). Another triangle, known as the *triangle of auscultation,* is situated behind the scapula. It is bounded above by the Trapezius, below by the Latissimus dorsi, and laterally by the vertebral border of the scapula; the floor is partly formed by the Rhomboideus major. If the scapula be drawn forwards by folding the arms across the chest, and the trunk bent forwards, parts of the sixth and seventh ribs and the interspace between them become subcutaneous and available for auscultation of the lung.

The **Rhomboideus major** (fig. 568) arises by tendinous fibres from the spinous processes of the second, third, fourth, and fifth thoracic vertebræ and the supraspinal ligament. The fibres of the muscle are directed downwards and lateralwards and are inserted into the vertebral border of the scapula between the triangular surface of the root of the spine and the inferior angle. Usually the insertion is an indirect one, the muscular fibres ending in a tendinous band which is fixed at its ends to the two points mentioned and joined to the vertebral border by a thin membrane; occasionally the arch is incomplete, and some of the muscular fibres are then inserted directly into the scapula.

Nerve-supply.—The Rhomboideus major is supplied by the fifth cervical through the dorsal scapular nerve.

Actions.—The Rhomboideus major retracts the scapula, and rotates it so that the inferior angle is carried backwards and upwards.

The **Rhomboideus minor** (fig. 568) arises from the lower part of the ligamentum nuchæ and from the spinous processes of the seventh cervical and first thoracic vertebræ; it is inserted into the base of the triangular smooth surface at the root of the spine of the scapula. It is usually separated from the Rhomboideus major by a slight interval, but the adjacent margins of the two muscles are occasionally united.

Nerve-supply.—The Rhomboideus minor is supplied by the fifth cervical nerve through the dorsal scapular nerve.

Action.—The Rhomboideus minor draws the scapula backwards, upwards and medialwards.

The **Levator scapulæ** (fig. 568) is situated at the back and side of the neck. It arises by tendinous slips from the transverse processes of the atlas and epistropheus and from the posterior tubercles of the transverse processes of the third and fourth cervical vertebræ. It is inserted into the vertebral border of the scapula, between the medial angle and the triangular smooth surface at the root of the spine.

Nerve-supply.—The Levator scapulæ is supplied directly by branches from the third and fourth cervical nerves, and by a branch from the fifth cervical nerve through the dorsal scapular nerve.

Actions.—If the cervical part of the vertebral column be fixed, the Levator scapulæ raises the medial angle of the scapula ; this produces a rotation of the scapula by which the point of the shoulder is depressed. If the shoulder be fixed, the muscle inclines the neck to the same side.

II. The Muscles connecting the Upper Extremity with the Anterior and Lateral Thoracic Walls

Pectoralis major.	Subclavius.
Pectoralis minor.	Serratus anterior.

The **superficial fascia** of the anterior thoracic region is continuous with that of the neck and upper extremity above, and of the abdomen below. It encloses the mamma and gives off numerous septa which pass into the gland to support its various lobes. From the fascia over the front of the mamma, fibrous processes pass forwards to the integument and mammary papilla ; these were called by Sir A. Cooper the *ligamenta suspensoria.*

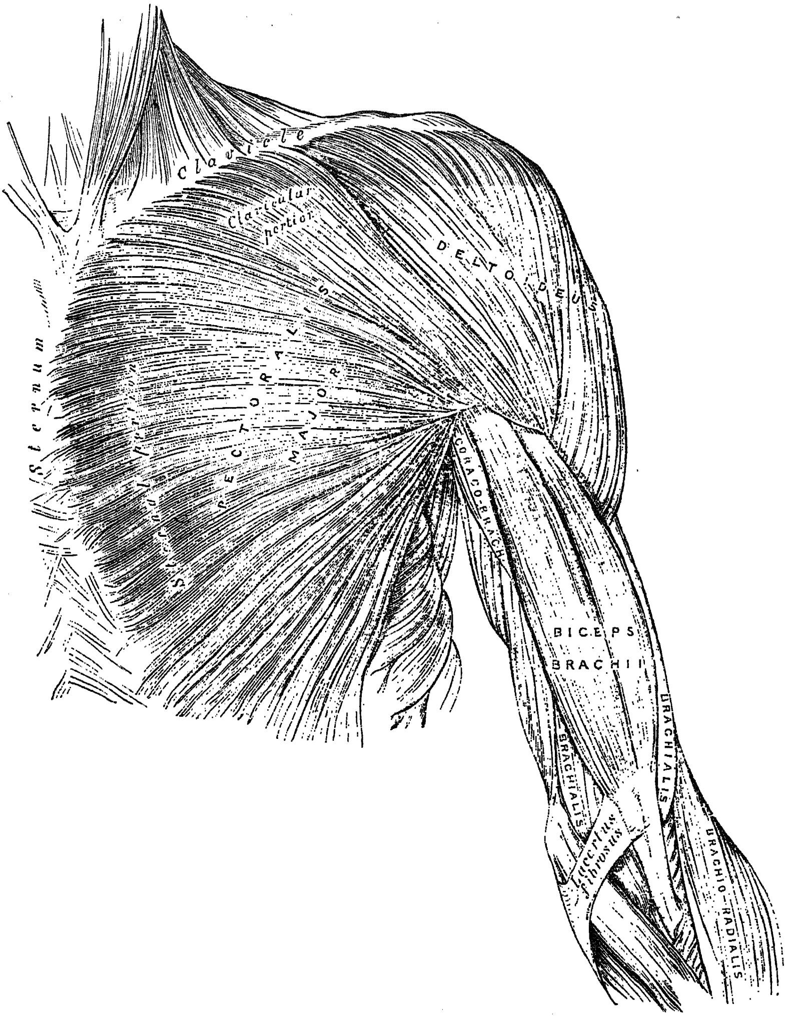
The **pectoral fascia** is a thin lamina, covering the surface of the Pectoralis major, and sending numerous prolongations between its fasciculi ; it is attached, in the middle line, to the front of the sternum ; above, to the clavicle ; laterally and below, it is continuous with the fascia of the shoulder, axilla, and thorax. It is very thin over the upper part of the Pectoralis major, but thicker in the interval between it and the Latissimus dorsi, where it closes in the axillary space and forms the *axillary fascia* ; this divides at the lateral margin of the Latissimus dorsi into two layers, one of which passes in front of, and the other behind this muscle ; these proceed as far as the spinous processes of the thoracic vertebræ, to which they are attached. As the fascia leaves the lower edge of the Pectoralis major to cross the floor of the axilla it sends a layer upwards under cover of the muscle ; this lamina splits to envelop the Pectoralis minor, and at the upper edge of this muscle is continuous with the coracoclavicular fascia. The hollow of the armpit, seen when the arm is abducted, is produced mainly by the traction of this fascia on the axillary floor, and hence the lamina is sometimes named the *suspensory ligament* of the axilla. At the lower part of the thoracic region the deep fascia is well developed, and is continuous with the fibrous sheath of the Rectus abdominis.

Applied Anatomy.—In cases of suppuration in the axilla, the pus is prevented from extending downwards by the axillary fascia, and therefore tends to spread upwards, beneath the pectoral muscles, towards the root of the neck. Early evacuation of the pus is therefore necessary. The incision should be made midway between the anterior and posterior axillary folds, so as to avoid the lateral thoracic and subscapular vessels, and the edge of the knife should be directed away from the axillary vessels.

The **Pectoralis major** (fig. 569) is a thick, triangular muscle situated at the upper and front part of the chest. It arises from the anterior surface of the sternal half of the clavicle ; from half the breadth of the anterior surface of the sternum, as low down as the attachment of the cartilage of the sixth or seventh rib ; from the cartilages of all the true ribs, with the exception, frequently, of the first, or seventh, or both, and from the aponeurosis of the Obliquus externus abdominis. From this extensive origin the fibres converge towards their insertion ; those arising from the clavicle pass obliquely downwards and lateralwards, and are usually separated from the rest by a slight interval ; those from the lower part of the sternum, and the cartilages of the lower true ribs, run upwards and lateralwards ; while the middle fibres pass horizontally. They all end in a flat tendon, about 5 cm. broad, which is inserted into the crest of the greater tubercle of the humerus. This tendon consists of two laminæ, placed one in front of the other, and usually blended together below. The anterior lamina, the thicker, receives the clavicular and the uppermost sternal fibres ; they are inserted in the same order as that in which they arise : that is to say, the most lateral of the clavicular fibres are inserted at the upper part of the anterior lamina, and the uppermost sternal fibres to the lower part of the lamina, which extends as low as the tendon of the Deltoideus and joins with it. The posterior lamina of the tendon receives

the attachment of the greater part of the sternal portion and the deep fibres, i.e. those from the costal cartilages. These deep fibres, and particularly those from the lower costal cartilages, turn backwards successively behind and reach a higher level than the superficial and upper ones, so that the tendon appears to be twisted. The posterior lamina of the tendon reaches higher on the humerus than the anterior, and gives off an expansion which covers

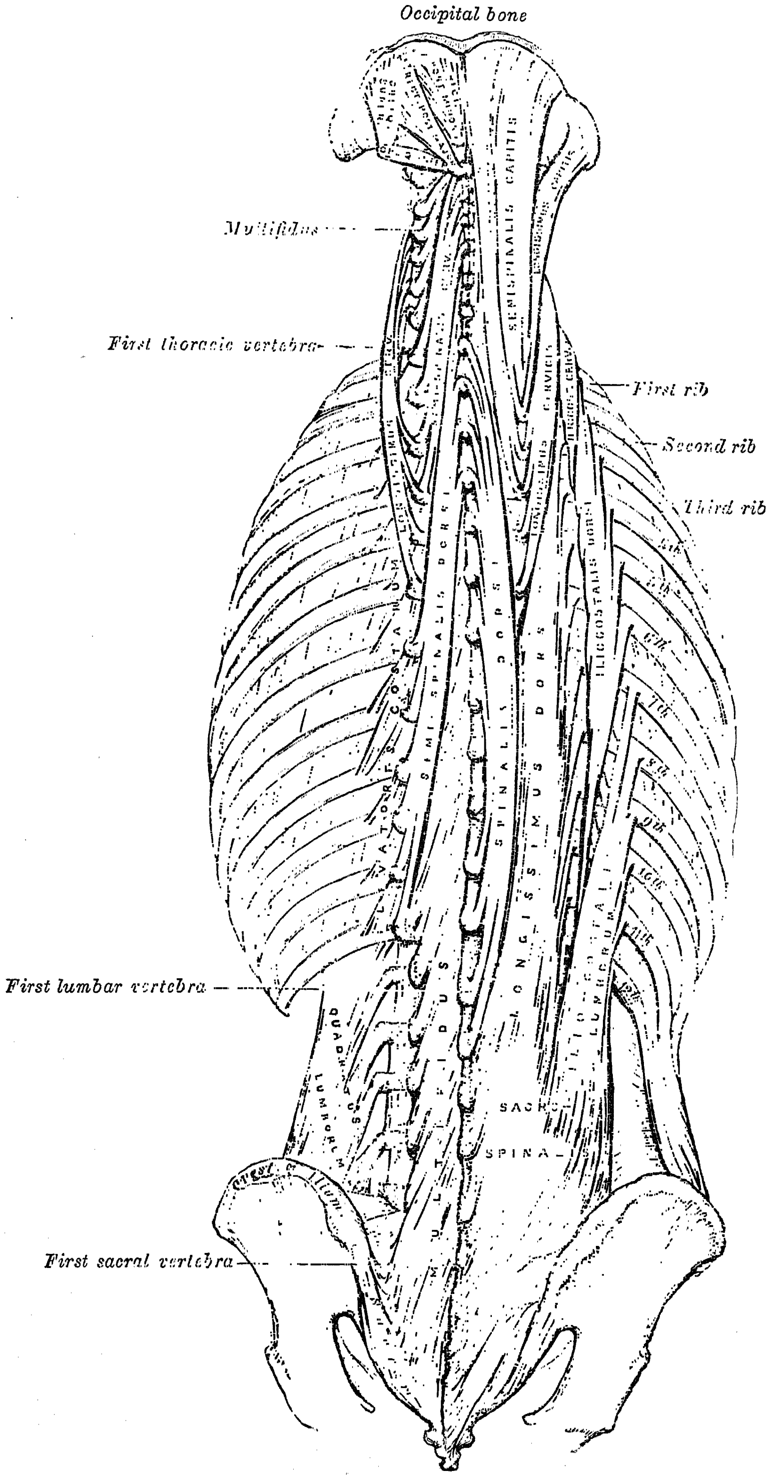
FIG. 569.—The superficial muscles of the front of the chest and arm. Left side.



the intertubercular sulcus and blends with the capsule of the shoulder-joint. From the deepest fibres of this lamina at its insertion an expansion is given off which lines the intertubercular sulcus, while from the lower border of the tendon a third expansion passes downwards to the fascia of the arm.

Relations.—In front of the Pectoralis major are the skin, superficial fascia, Platysma, anterior and middle supraclavicular nerves, mamma, and deep fascia; its *posterior surface* is in contact with the sternum, ribs and costal cartilages, coracoclavicular fascia, Subclavius, Pectoralis minor, Serratus anterior, and Intercostales; it forms the anterior wall of the axillary space, and covers the axillary vessels and nerves and the upper parts of the Biceps brachii and Coracobrachialis. Its *upper border* is separated from the Deltoideus by a slight interspace, the *deltoideopectoral triangle*, or *infraclavicular fossa*,

FIG. 546.—The deep muscles of the back.

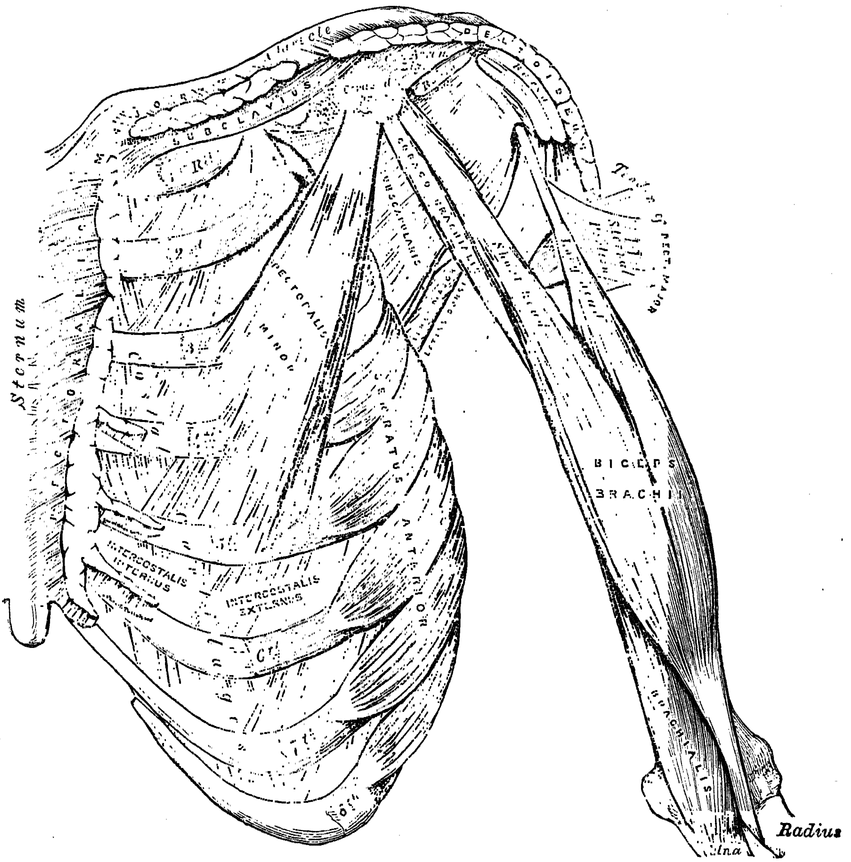


Nerve-supply.—The Subclavius is supplied by a branch which derives its fibres from the fifth and sixth cervical nerves.

Action.—The Subclavius pulls the shoulder downwards and forwards.

The **Serratus anterior** (Serratus magnus) (fig. 570) is a muscular sheet, situated between the ribs and scapula at the upper and lateral parts of the chest. It arises by fleshy slips or digitations from the outer surfaces and superior borders of the upper eight or nine ribs, and from the aponeuroses covering the intervening Intercostales. Each digitation arises from the

FIG. 570.—The deep muscles of the front of the chest and arm. Left side.



corresponding rib, but the first springs in addition from the second rib, and from the fascia covering the first intercostal space. The lower four slips interdigitate with the upper five slips of the Obliquus externus abdominis. From this extensive attachment the fibres pass backwards, closely applied to the chest-wall, and are inserted into the ventral surface of the vertebral border of the scapula in the following manner. The first digitation is inserted into a triangular area on the ventral surface of the medial (superior) angle. The next two or three digitations spread out to form a thin, triangular sheet, the base of which is directed backwards and is inserted into nearly the whole length of the ventral surface of the vertebral border. The lower five or six digitations converge to form a fan-shaped mass, the apex of which is inserted, by muscular and tendinous fibres, into a triangular impression on the ventral surface of the inferior angle.

Nerve-supply.—The Serratus anterior is supplied by the long thoracic nerve, which is derived from the fifth, sixth, and seventh cervical nerves.

Actions.—The Serratus anterior, as a whole, carries the scapula forwards, and at the same time raises the vertebral border of the bone. Its lower and stronger fibres move the lower angle forwards and assist the Trapezius in rotating the bone at the sternoclavicular joint, and thus aid this muscle in raising the acromion. It is also an assistant to the Deltoideus in raising the arm, inasmuch as during the action of this latter muscle it fixes the scapula and so steadies the glenoid cavity on which the head of the humerus moves. After the Deltoideus has raised the arm to a right angle with the trunk, the Serratus anterior and the Trapezius, by rotating the scapula, raise the arm into an almost vertical position.

Applied Anatomy.—When the Serratus anterior is paralysed, the vertebral border, and especially the lower angle of the scapula, leave the ribs and stand out prominently on the surface, giving a peculiar ' winged ' appearance to the back (p. 279). The patient is unable to raise the arm, and an attempt to do so is followed by a further projection of the lower angle of the scapula from the back of the thorax.

The long thoracic nerve supplying the Serratus anterior is exposed in the operation for removal of cancer of the breast, and should always be carefully preserved.

III. The Muscles of the Shoulder

Deltoideus.	Infraspinatus.
Subscapularis.	Teres minor.
Supraspinatus.	Teres major.

The **deep fascia** covering the Deltoideus invests the muscle, and sends numerous septa between the fasciculi. In front, it is continuous with the pectoral fascia ; behind, where it is thick and strong, with the fascia infraspinata ; above, it is attached to the clavicle, the acromion, and the spine of the scapula ; below, it is continuous with the brachial fascia.

The **Deltoideus** (fig. 569) is a thick, triangular muscle, which covers the shoulder-joint. It arises from the anterior border and upper surface of the lateral one-third of the clavicle ; from the lateral margin and upper surface of the acromion, and from the lower lip of the posterior border of the spine of the scapula, as far back as the triangular surface at its medial end. The fibres converge towards their insertion, the middle passing vertically, the anterior inclining backwards, and the posterior forwards ; they unite in a thick tendon which is inserted into the deltoid tuberosity on the lateral side of the body of the humerus. At its insertion the tendon gives off an expansion to the deep fascia of the arm. This muscle is remarkably coarse in texture, and the part arising from the acromion consists of oblique fibres ; these arise in a bipennate manner from the sides of tendinous septa, generally four in number, which pass downwards from the acromion into the muscle. These oblique fibres are inserted into similar tendinous septa, generally three in number, which ascend from the insertion of the muscle and alternate with the descending septa. The portions of the muscle arising from the clavicle and spine of the scapula are not arranged in this manner, but are inserted into the margins of the inferior tendon.

Relations.—Its *superficial surface* is in relation with the skin, the superficial and deep fasciæ, Platysma, posterior supraclavicular, and lateral brachial cutaneous nerves. Its *deep surface* is separated from the articular capsule of the shoulder-joint by a large bursa, and covers the coracoid process, coraco-acromial ligament, Pectoralis minor, Coracobrachialis, both heads of the Biceps brachii, the tendon of the Pectoralis major, the insertions of the Supraspinatus, Infraspinatus, and Teres minor, the long and lateral heads of the Triceps brachii, the humeral circumflex vessels, the axillary nerve, and the surgical neck and upper part of the body of the humerus. Its *anterior border* is separated at its upper part from the Pectoralis major by the deltoideopectoral triangle in which the cephalic vein and deltoid branch of the thoraco-acromial artery lie; lower down the two muscles are in contact. Its *posterior border* rests on the Infraspinatus and Triceps brachii.

Nerves.—The Deltoideus is supplied by the fifth and sixth cervical nerves through the axillary nerve.

Actions.—The Deltoideus raises the arm from the side, so as to bring it at right angles with the trunk. Its anterior fibres draw the arm forwards; and its posterior fibres draw it backwards.

Applied Anatomy.—The Deltoideus is very liable to atrophy, and in this condition dislocation of the shoulder-joint is simulated, as there is flattening of the shoulder and apparent prominence of the acromion; the distance also between the acromion and the head of the bone is increased, and the tips of the fingers can be inserted between them.

The **subscapular fascia** is a thin membrane attached to the entire circumference of the subscapular fossa, and giving origin by its deep surface to some of the fibres of the Subscapularis.

The **Subscapularis** (fig. 570) is a large triangular muscle which fills the subscapular fossa, and arises from its medial two-thirds and from the lower two-thirds of the groove on the axillary border of the scapula. Some fibres arise from tendinous laminæ which intersect the muscle and are attached to ridges on the bone; others from an aponeurosis, which separates the muscle from the Teres major and the long head of the Triceps brachii. The fibres pass lateralwards, and, gradually converging, end in a tendon which is inserted into the lesser tubercle of the humerus and the front of the capsule of the shoulder-joint. The tendon of the muscle is separated from the neck of the scapula by a large bursa, which communicates with the cavity of the shoulder-joint through an aperture in the articular capsule.

Relations.—The *anterior surface* of this muscle forms a considerable part of the posterior wall of the axilla, and is in relation with the Serratus anterior, Coracobrachialis, and Biceps brachii, the axillary vessels and brachial plexus of nerves, and the subscapular vessels and nerves. Its *posterior surface* is in relation with the scapula and the capsule of the shoulder-joint. Its *lower border* is in contact with the Teres major and Latissimus dorsi.

Nerves.—The Subscapularis is supplied by the fifth and sixth cervical nerves through the upper and lower subscapular nerves.

Actions.—The Subscapularis rotates the head of the humerus inwards; when the arm is raised, it draws the humerus forwards and downwards. It is a powerful defence to the front of the shoulder-joint.

The **fascia supraspinata** completes the osseofibrous case in which the Supraspinatus muscle is contained, and its deep surface gives origin to some of the fibres of the muscle. It is thick medially, but thinner laterally under the coraco-acromial ligament.

The **Supraspinatus** (fig. 571) occupies the supraspinatous fossa, arising from its medial two-thirds, and from the fascia supraspinata. The muscular fibres pass under the acromion, and converge to a tendon which crosses the upper part of the shoulder-joint and is inserted into the highest of the three impressions on the greater tubercle of the humerus; the tendon is intimately adherent to the capsule of the shoulder-joint.

Nerve-supply.—The Supraspinatus is supplied by the fifth and sixth cervical nerves through the suprascapular nerve.

Action.—The Supraspinatus abducts the arm.

The **fascia infraspinata** is a dense fibrous membrane, covering the Infraspinatus muscle and fixed to the circumference of the infraspinatous fossa; its deep surface gives origin to some fibres of that muscle. It is intimately attached to the deltoid fascia along the overlapping border of the Deltoideus.

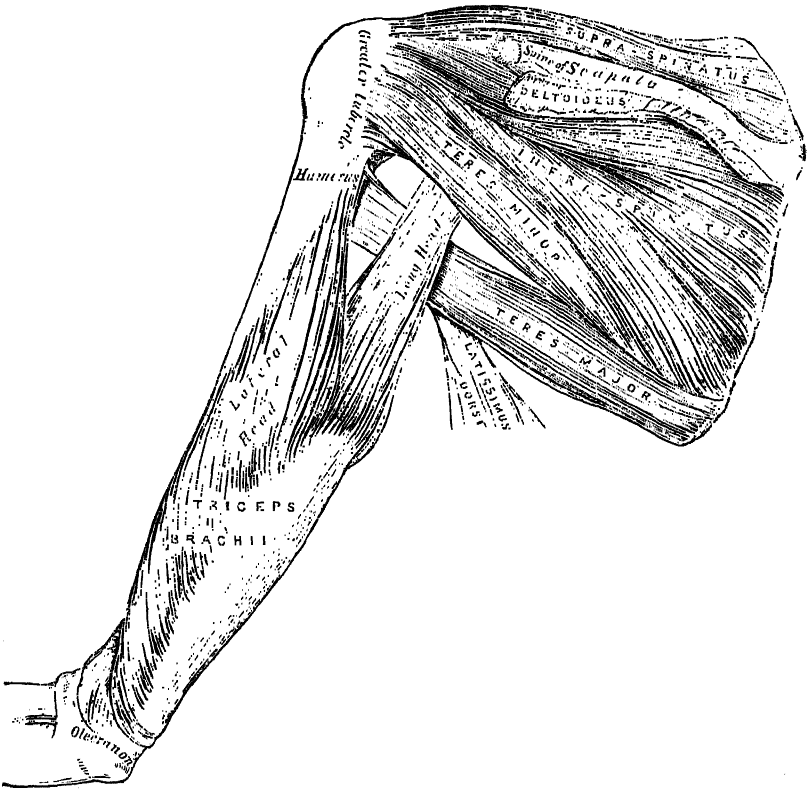
The **Infraspinatus** (fig. 571) is a thick triangular muscle, which occupies the chief part of the infraspinatous fossa; it arises by fleshy fibres from the medial two-thirds of the fossa, and by tendinous fibres from the ridges on its surface: it also arises from the fascia infraspinata which covers it and separates it from the Teretes major et minor. The fibres converge to a tendon, which glides over the lateral border of the spine of the scapula, and, passing across the posterior part of the capsule of the shoulder-joint, is inserted into the middle impression on the greater tubercle of the humerus. The tendon of this muscle is sometimes separated from the capsule of the shoulder-joint by a bursa which may communicate with the joint-cavity.

Nerve-supply.—The Infraspinatus is supplied by the fifth and sixth cervical nerves through the suprascapular nerve.

Action.—The Infraspinatus rotates the arm outwards.

The **Teres minor** (fig. 571) is a narrow, elongated muscle, which arises from the dorsal surface of the axillary border of the scapula for the upper two-thirds of its extent, and from two aponeurotic laminæ, one of which separates it from the Infraspinatus, the other from the Teres major. Its fibres run obliquely upwards and lateralwards; the upper ones end in a tendon which is inserted into the lowest of the three impressions on the greater tubercle of the humerus; the lower fibres are inserted directly into the humerus immediately below this

FIG. 571.—The muscles on the dorsum of the scapula, and the Triceps brachii. Left side.



impression and just above the origin of the lateral head of the Triceps brachii. The tendon of this muscle passes across, and is united with, the posterior part of the capsule of the shoulder-joint.

Nerve-supply.—The Teres minor is supplied by the fifth cervical nerve through the axillary nerve.

Action.—The Teres minor rotates the arm outwards.

The **Teres major** (fig. 571) is a thick, somewhat flattened muscle, which arises from the oval area on the dorsal surface of the inferior angle of the scapula, and from the fibrous septa interposed between the muscle and the Teres minor and Infraspinatus; the fibres are directed upwards and lateralwards and end in a flat tendon, about 5 cm. long, which is inserted into the crest of the lesser tubercle of the humerus. At its insertion the tendon lies behind that of the Latissimus dorsi, from which it is separated by a bursa, the two tendons being, however, united along their lower borders for a short distance.

Nerve-supply.—The Teres major is supplied by the fifth and sixth cervical nerves through the lower subscapular nerve

Actions.—The Teres major draws the humerus medialwards and backwards, and rotates it inwards.

IV. The Muscles of the Arm

Coracobrachialis.	Brachialis.
Biceps brachii.	Triceps brachii.

The **brachial fascia** or deep fascia of the arm is continuous with that covering the Deltoideus and the Pectoralis major; it forms a thin, loose sheath for the muscles of the arm, and sends septa between them; it is composed of fibres disposed in a circular or spiral direction, and connected together by vertical and oblique fibres. It is thin over the Biceps brachii, but thicker where it covers the Triceps brachii, and over the epicondyles of the humerus: it is strengthened by fibrous aponeuroses, derived from the Pectoralis major and Latissimus dorsi medially, and from the Deltoideus laterally. On either side it gives off a strong intermuscular septum, which is attached to the corresponding supracondylar ridge and epicondyle of the humerus.

The *lateral intermuscular septum* extends from the lower part of the crest of the greater tubercle of the humerus, along the lateral supracondylar ridge, to the epicondyle; it is blended with the tendon of the Deltoideus, gives attachment to the Triceps brachii behind, to the Brachialis, Brachioradialis and Extensor carpi radialis longus in front, and is perforated by the radial nerve and arteria profunda brachii. The *medial intermuscular septum,* thicker than the preceding, extends from the lower part of the crest of the lesser tubercle of the humerus below the Teres major, along the medial supracondylar ridge to the epicondyle; it is blended with the tendon of the Coracobrachialis, and affords attachment to the Triceps brachii behind and the Brachialis in front. It is perforated by the ulnar nerve, the superior ulnar collateral artery, and the posterior branch of the inferior ulnar collateral artery.

At the elbow, the brachial fascia is attached to the epicondyles of the humerus and the olecranon of the ulna, and is continuous with the antibrachial fascia. Just below the middle of the medial side of the arm, an oval opening in the fascia transmits the basilic vein and some lymphatic vessels.

The **Coracobrachialis** (figs. 570, 572) is situated at the upper and medial part of the arm. It arises from the apex of the coracoid process, in common with the tendon of the short head of the Biceps brachii, and by muscular fibres from the upper 10 cm. of this tendon; it is inserted into an impression at the middle of the medial surface and border of the body of the humerus between the origins of the Triceps brachii and Brachialis.

Relations.—It is perforated by the musculocutaneous nerve, and is in relation, in *front*, with the Pectoralis major above, and at its insertion with the brachial vessels and median nerve which cross it; *behind*, with the tendons of the Subscapularis, Latissimus dorsi, and Teres major, the medial head of the Triceps brachii, the humerus, and the anterior humeral circumflex vessels; by its *medial border*, with the third part of the axillary artery, the upper part of the brachial artery, the median and musculocutaneous nerves; by its *lateral border*, with the Biceps brachii and Brachialis.

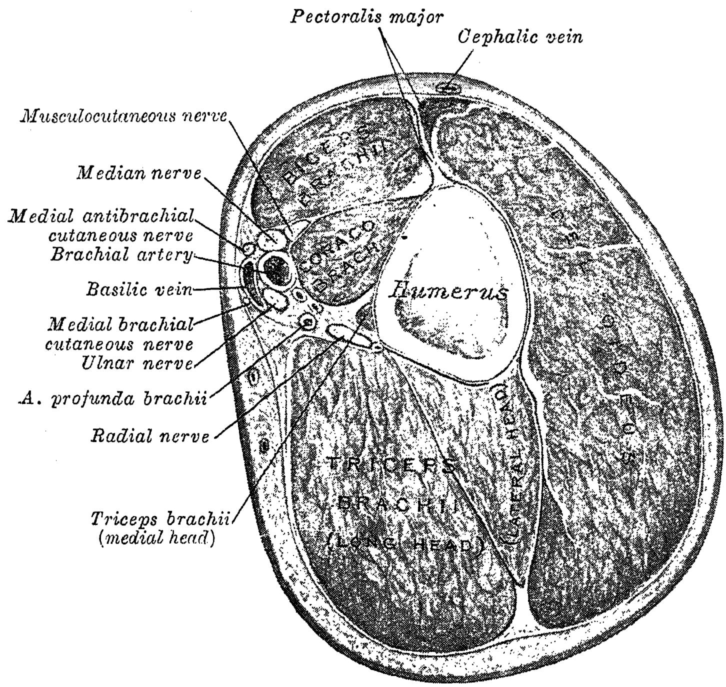
Nerve-supply.—The Coracobrachialis is supplied by the seventh cervical nerve through the musculocutaneous nerve.

Action.—The Coracobrachialis draws the arm forwards and medialwards.

The **Biceps brachii** (figs. 570, 572, 573), a long fusiform muscle placed on the front of the arm, has received its name from the circumstance that it has two heads of origin. The *short head* arises by a thick flattened tendon from the apex of the coracoid process, in common with the Coracobrachialis. The *long head* arises by a long narrow tendon from the supraglenoid tuberosity at the apex of the glenoid cavity, and is continuous with the glenoidal labrum (p. 380). The tendon of the long head, enclosed in a sheath of the synovial stratum of the articular capsule of the shoulder-joint, arches over the head of the

humerus ; it emerges from the joint through an opening in the articular capsule close to its humeral attachment and descends in the intertubercular sulcus ; it is retained in the sulcus by the transverse humeral ligament and by a fibrous expansion from the tendon of the Pectoralis major. Each tendon is succeeded by an elongated muscular belly, and the two bellies, although closely applied to each other, can be readily separated until within about 7·5 cm. of the elbow-joint. Here they end in a flattened tendon, which is inserted into the rough posterior portion of the tuberosity of the radius, a bursa being interposed between the tendon and the front part of the tuberosity. As the tendon of the muscle approaches the radius it is twisted upon itself, so that its anterior

FIG. 572.—A transverse section through the arm at the junction of the proximal with the intermediate one-third of the humerus.



surface becomes lateral and is applied to the tuberosity of the radius at its insertion. Opposite the bend of the elbow the tendon gives off, from its medial side, a broad aponeurosis, the *lacertus fibrosus* or *bicipital fascia*, which passes obliquely downwards and medialwards across the brachial artery and is continuous with the deep fascia covering the origins of the flexor muscles of the forearm (fig. 569). With very little force the tendon of insertion can be split down to the radial tuberosity, when it can be seen that the anterior portion of the tendon receives the fibres of the short head, and the posterior portion those of the long head.

A third head to the Biceps brachii is occasionally found, arising at the upper and medial part of the Brachialis, with which it is blended, and inserted into the lacertus fibrosus and medial side of the tendon of the muscle; in most cases this additional slip lies behind the brachial artery. In some instances the third head consists of two slips, which pass down, one in front of, the other behind the artery.

Relations.—The Biceps brachii is overlapped above by the Pectoralis major and Deltoideus; in the rest of its extent it is covered by the fasciæ and skin. Above, its long head passes through the shoulder-joint, and its short head rests on the joint and the upper part of the humerus; below, it lies on the Brachialis, the musculocutaneous nerve, and the Supinator. Its *medial border* is in relation with the Coracobrachialis, and overlaps the

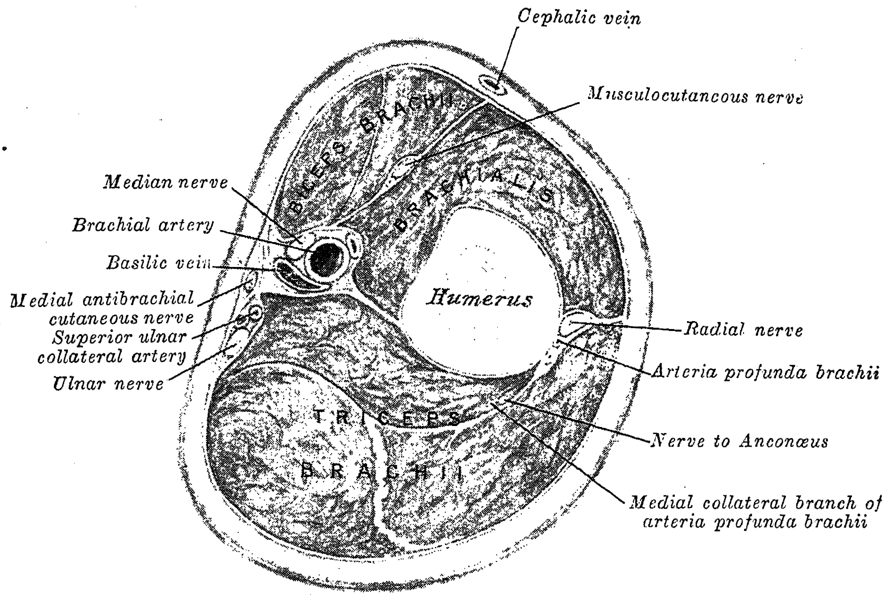
brachial vessels and median nerve; its *lateral border*, with the Deltoideus and Brachioradialis.

Nerve-supply.—The Biceps brachii is supplied by the fifth and sixth cervical nerves through the musculocutaneous nerve.

Actions.—The Biceps brachii is a powerful supinator of the forearm; it also flexes the elbow-joint, and to a slight extent the shoulder-joint. Through the lacertus fibrosus it is a tensor of the antibrachial fascia.

Applied Anatomy.—The long tendon of the Biceps brachii is sometimes dislocated from the intertubercular sulcus. When this occurs, the arm is fixed in a position of abduction, but the head of the humerus can be felt in its proper position. The tendon can generally be replaced by flexing the forearm on the arm and rotating the limb. Rupture of the long tendon of the Biceps brachii may also take place.

FIG. 573.—A transverse section through the arm, a little below the middle of the body of the humerus.



The **Brachialis** (Brachialis anticus) (figs. 570, 573, 574) covers the front of the elbow-joint and the lower one-half of the humerus. It arises from the lower one-half of the front of the humerus, commencing above at the insertion of the Deltoideus, which it embraces by two angular processes, and extending below to within 2·5 cm. of the margin of the articular surface. It also arises from the intermuscular septa, but more extensively from the medial than the lateral; it is separated from the lower part of the lateral intermuscular septum by the Brachioradialis and Extensor carpi radialis longus. Its fibres converge to a thick tendon, which is inserted into the tuberosity of the ulna and the rough depression on the anterior surface of the coronoid process.

Relations.—It is in relation, in *front*, with the Biceps brachii, the brachial vessels, musculocutaneous and median nerves; *behind*, with the humerus and articular capsule of the elbow-joint; by its *medial border*, with the Pronator teres, and with the medial intermuscular septum which separates it from the Triceps brachii and the ulnar nerve; by its *lateral border*, with the radial nerve, radial recurrent artery, the Brachioradialis, and Extensor carpi radialis longus.

Nerve-supply.—The Brachialis is chiefly supplied by the fifth and sixth cervical nerves through the musculocutaneous nerve, but receives an additional filament from the seventh cervical through the radial nerve.

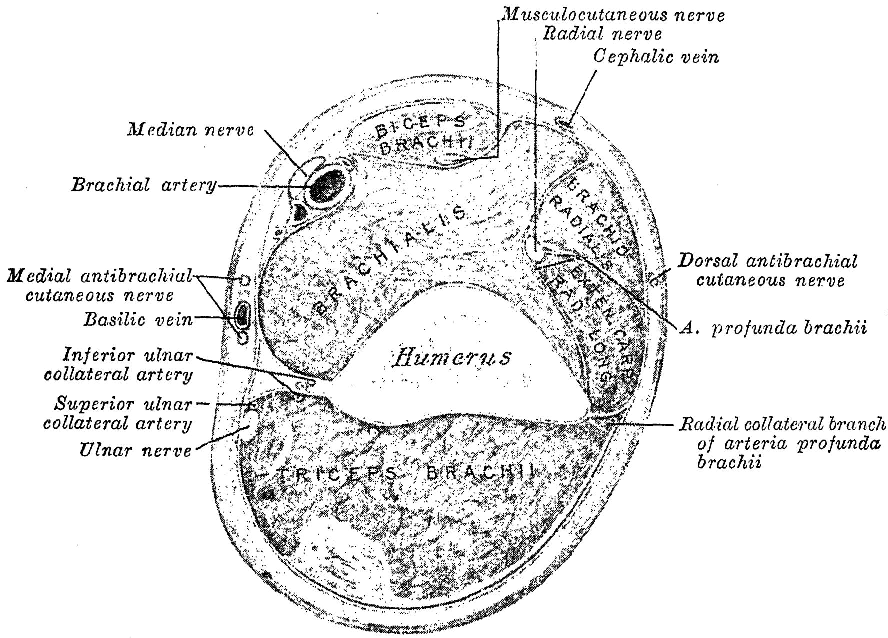
Action.—The Brachialis flexes the elbow-joint.

The **Triceps brachii** (figs. 571, 572, 573, 574), situated on the back of the arm, is of large size, and arises by three heads (long, lateral, and medial), hence its name.

The *long head* arises by a flattened tendon from the infraglenoid tuberosity of the scapula, being blended at its upper part with the capsule of the shoulder-joint; the muscular fibres pass downwards between the other two heads of the muscle, and join with them in the tendon of insertion.

The *lateral head* arises from a narrow ridge on the posterior surface of the body of the humerus, extending from the insertion of the Teres minor to the upper part of the sulcus for the radial nerve, and from the lateral border of the humerus and the lateral intermuscular septum; the fibres from this origin converge towards the tendon of insertion.

Fig. 574.—A transverse section through the arm, 2 cm. proximal to the medial epicondyle of the humerus.



The *medial head* arises from the posterior surface of the body of the humerus, below the sulcus for the radial nerve; it is narrow and pointed above, and extends from the insertion of the Teres major to within 2·5 cm. of the trochlea humeri; it also arises from the medial border of the bone and from the back of the whole length of the medial intermuscular septum. Some of the fibres are directed downwards to the olecranon, while others converge to the tendon of insertion.

The tendon of insertion of the Triceps brachii begins about the middle of the muscle. It consists of two aponeurotic laminæ, one of which covers the back of the lower one-half of the muscle; the other is more deeply seated in the substance of the muscle. After receiving the attachment of the muscular fibres, the two lamellæ join together above the elbow, and are inserted, for the most part, into the posterior portion of the upper surface of the olecranon; a band of fibres is, however, continued downwards, on the lateral side, over the Anconæus, to blend with the antibrachial fascia.

The long head of the Triceps brachii descends between the Teres minor and Teres major, dividing the triangular space between these two muscles and the humerus into two smaller spaces, one triangular, the other quadrangular (fig. 571). The triangular space contains the scapular circumflex vessels; it is bounded by the Teres minor above, the Teres major below, and the scapular head of the Triceps

laterally. The quadrangular space transmits the posterior humeral circumflex vessels and the axillary nerve; it is bounded by the Subscapularis, the Teres minor and the capsule of the shoulder-joint above, the Teres major below, the long head of the Triceps brachii medially, and the humerus laterally.

The **Subanconæus** is the name given to a few fibres which spring from the deep surface of the lower part of the Triceps brachii, and are inserted into the posterior part of the articular capsule of the elbow-joint.

Nerves.—The Triceps brachii is supplied by the sixth, seventh and eighth cervical nerves through the radial nerve.*

Actions.—The Triceps brachii is the great extensor muscle of the forearm. When the arm is extended, the long head of the muscle may assist in drawing the humerus backwards and in adducting it to the thorax. The long head supports the under part of the shoulder-joint. The Subanconæus draws up the posterior part of the articular capsule of the elbow-joint during extension of the forearm.

Applied Anatomy.—The insertion of the Triceps brachii into the deep fascia of the forearm is of importance in the operation of excision of the elbow, and should always be carefully preserved. By means of it the patient is enabled to extend the forearm, a movement which would otherwise be accomplished mainly by gravity—that is to say, by allowing the forearm to drop by its own weight.

V. The Muscles of the Forearm

The **antibrachial fascia** (deep fascia of the forearm), continuous above with the brachial fascia, is a dense investment, which forms a general sheath for the muscles in this region; it is attached, behind, to the olecranon and dorsal border of the ulna, and sends off from its deep surface numerous intermuscular septa. It gives origin to muscular fibres, especially at the upper part of the medial and lateral sides of the forearm, and forms the boundaries of a series of cone-shaped cavities, in which the muscles are contained; transverse septa are given off both on the volar and dorsal surfaces of the forearm, separating the deep from the superficial layers of muscles. It is much thicker on the dorsal than on the volar surface, and at the lower than at the upper part of the forearm, and is strengthened above by tendinous fibres derived from the Biceps brachii in front, and from the Triceps brachii behind. Over the flexor tendons as they approach the wrist it is especially thickened, and forms the volar carpal ligament. This is continuous with the transverse carpal ligament, and forms a sheath for the tendon of the Palmaris longus which passes over the transverse carpal ligament to be inserted into the palmar aponeurosis. Behind, near the wrist joint, it is thickened by the addition of many transverse fibres, and forms the dorsal carpal ligament. Apertures exist in the fascia for the passage of vessels and nerves; one of these apertures, of large size and situated at the front of the elbow, transmits a communicating branch between the superficial and deep veins.

The antibrachial or forearm muscles consist of a volar and a dorsal group.

1. The Volar Antibrachial Muscles

These muscles are divided for convenience of description into two groups, superficial and deep.

(*a*) *Superficial Group* (fig. 575)

Pronator teres. Palmaris longus.
Flexor carpi radialis. Flexor carpi ulnaris.
Flexor digitorum sublimis.

The muscles of this group take origin from the medial epicondyle of the humerus by a common tendon; they receive additional fibres from the anti-

* Wilfred Harris (*Journal of Anatomy*, vol. xxxviii.) is of opinion that the Triceps brachii is mainly supplied by the sixth and seventh cervical nerves.

brachial fascia near the elbow, and from the septa which pass from this fascia between the individual muscles.

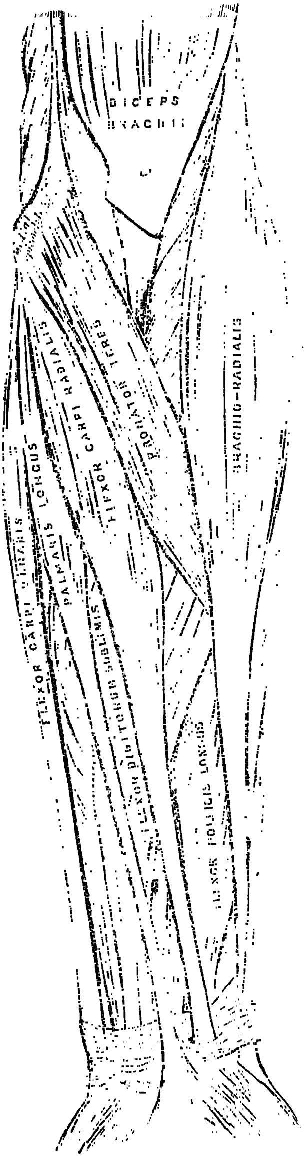


Fig. 575.—The left volar antibrachial muscles. Superficial group.

The **Pronator teres** (figs. 575, 576) has a humeral and an ulnar head of origin. The *humeral head*, the larger and more superficial, arises immediately above the medial epicondyle, and from the tendon common to the origin of the other muscles; also from the intermuscular septum between it and the Flexor carpi radialis and from the antibrachial fascia. The smaller *ulnar head* arises from the medial side of the coronoid process of the ulna, and joins the humeral head at an acute angle. The median nerve enters the forearm between the two heads of the muscle, and is separated from the ulnar artery by the ulnar head. The muscle passes obliquely across the forearm, and ends in a flat tendon, which is inserted into a rough impression at the middle of the lateral surface of the body of the radius. The lateral border of the muscle forms the medial boundary of a triangular hollow, which is situated in front of the elbow-joint and contains the median nerve, brachial artery, and tendon of the Biceps brachii.

Nerve-supply.—The Pronator teres is supplied by the sixth cervical nerve through the median nerve.

Actions.—The Pronator teres rotates the radius upon the ulna, turning the palm of the hand backwards; it also flexes the elbow-joint.

Applied Anatomy.—This muscle, when suddenly brought into active use, as in the game of lawn-tennis, is apt to be strained, producing slight swelling, tenderness, and pain on putting the muscle into action. This is known as 'lawn-tennis arm.'

The **Flexor carpi radialis** (figs. 575, 576, 579) lies on the medial side of the Pronator teres. It arises from the medial epicondyle by the common tendon, from the antibrachial fascia, and from the intermuscular septa between it and the adjacent muscles. Slender and aponeurotic in structure at its commencement, it increases in size, and ends in a long tendon which passes through a canal in the lateral part of the transverse carpal ligament and through a groove on the greater multangular bone; the groove is converted into a canal by fibrous tissue and lined by a mucous sheath. The tendon is inserted into the base of the second metacarpal bone, and sends a slip to the base of the third metacarpal bone. In the lower part of the forearm the radial artery lies between the tendon of this muscle and that of the Brachioradialis.

Nerve-supply.—The Flexor carpi radialis is supplied by the sixth cervical nerve through the median nerve.

Action.—The Flexor carpi radialis flexes the wrist.

The **Palmaris longus** (figs. 575, 576, 587) is a slender, fusiform muscle, lying on the medial side of the Flexor carpi radialis. It arises from the medial epicondyle of the humerus by the common tendon, from the intermuscular septa between it and the adjacent muscles, and from the antibrachial fascia. It ends in a long slender tendon which passes over the upper part of the transverse carpal ligament and is inserted into the anterior surface of the

distal one-half of this ligament and into the central part of the palmar aponeurosis, frequently sending a tendinous slip to the short muscles of the thumb. Just above the wrist, the median nerve lies deep to the tendon.

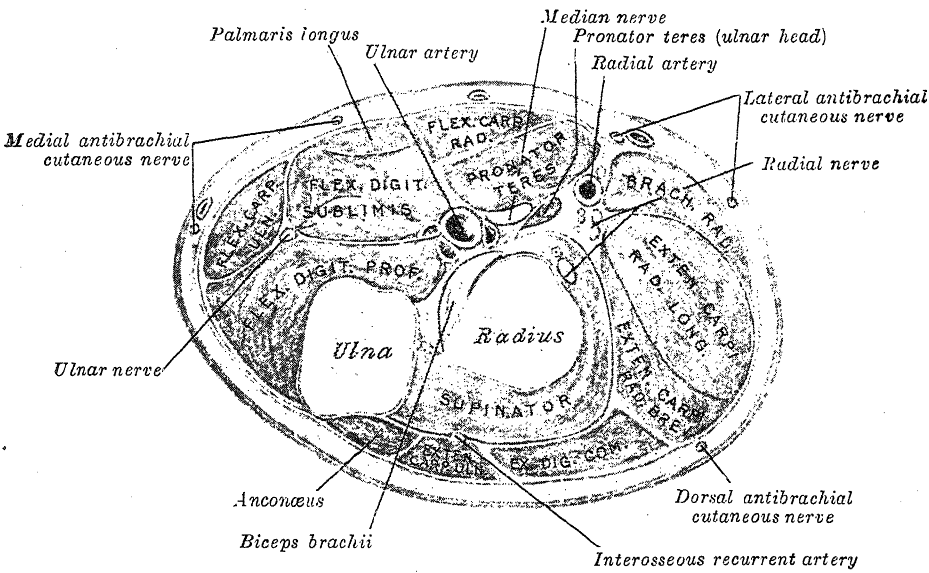
This muscle is often absent, and is subject to very considerable variations: it may be tendinous above and muscular below, or muscular in the middle with a tendon above and below; it may consist of two muscular bundles with a central tendon; or may be represented solely by a tendinous band.

Nerve-supply.—The Palmaris longus is supplied by the sixth cervical nerve through the median nerve.

Actions.—The Palmaris longus tightens the palmar aponeurosis and flexes the wrist.

The **Flexor carpi ulnaris** (figs. 575, 576, 579) lies along the ulnar side of the forearm. It arises by two heads, humeral and ulnar, connected by a

FIG. 576.—A transverse section through the forearm at the level of the radial (bicipital) tuberosity.



tendinous arch, beneath which the ulnar nerve passes downwards and the posterior ulnar recurrent artery upwards. The *humeral head* is very small and arises from the medial epicondyle of the humerus by the common tendon; the *ulnar head* arises from the medial margin of the olecranon and from the upper two-thirds of the dorsal border of the ulna by an aponeurosis common to it and the Extensor carpi ulnaris and Flexor digitorum profundus; and from the intermuscular septum between it and the Flexor digitorum sublimis. The fibres end in a tendon, which occupies the anterior part of the distal one-half of the muscle and is inserted into the pisiform bone, whence it is prolonged to the hamate and fifth metacarpal bones by the pisohamate and pisometacarpal ligaments; it is also attached by a few fibres to the transverse carpal ligament. The ulnar vessels and nerve lie on the lateral side of the tendon of insertion of this muscle.

Nerve-supply.—The Flexor carpi ulnaris is supplied by the eighth cervical and first thoracic nerves through the ulnar nerve.

Actions.—The Flexor carpi ulnaris flexes the wrist and slightly adducts the hand.

The **Flexor digitorum sublimis** (figs. 575, 576, 579) is dorsal to the preceding muscle; it is the largest of the muscles of the superficial group, and arises by two heads, humero-ulnar and radial. The *humero-ulnar head* arises from the medial epicondyle of the humerus by the common tendon, from the ulnar collateral ligament of the elbow-joint, from the intermuscular septa

between it and the preceding muscles, and from the medial side of the coronoid process, above the ulnar origin of the Pronator teres. The *radial head*, a thin sheet of muscle, arises from the oblique line of the radius, extending from the radial tuberosity to the insertion of the Pronator teres. The muscle speedily separates into two planes of muscular fibres, superficial and deep : the superficial plane divides into two parts which end in tendons for the middle and ring fingers ; the deep plane gives off a muscular slip to join that part of the superficial plane which is associated with the tendon of the ring finger, and then divides into two parts, which end in tendons for the index and little fingers. As the four tendons pass beneath the transverse carpal ligament into the palm of the hand, they are arranged in pairs, the superficial pair going to the middle and ring fingers, the deep pair to the index and little fingers. The tendons diverge from one another in the palm and form deep relations to the superficial volar arch and digital branches of the median and ulnar nerves. Opposite the bases of the first phalanges each tendon divides into two slips, to allow of the passage of the corresponding tendon of the Flexor digitorum profundus ; the two slips then reunite, partially decussate, and form a grooved channel for the reception of the tendon of the Flexor digitorum profundus. Finally the tendon divides and is inserted into the sides of the second phalanx about its middle.

Nerve-supply.—The Flexor digitorum sublimis is supplied by the seventh and eighth cervical and first thoracic nerves through the median nerve.

Actions.—The Flexor digitorum sublimis flexes first the middle and then the proximal phalanges. It also acts as a flexor of the wrist.

(*b*) *Deep Group* (fig. 577)

Flexor digitorum profundus. Flexor pollicis longus.
Pronator quadratus.

The **Flexor digitorum profundus** (figs. 576, 577, 579) is situated on the ulnar side of the forearm, deep to the superficial flexors. It arises from the upper three-fourths of the volar and medial surfaces of the body of the ulna, embracing the insertion of the Brachialis above, and extending to within a short distance of the Pronator quadratus below. It also arises from a depression on the medial side of the coronoid process of the ulna, and from the upper three-fourths of the dorsal border of the bone by an aponeurosis, in common with the Flexor and Extensor carpi ulnaris ; it also springs from the ulnar half of the interosseous membrane. The muscle ends in four tendons which run behind the transverse carpal ligament, dorsal to the tendons of the Flexor digitorum sublimis. The portion of the muscle for the index finger is usually distinct throughout, but the tendons for the middle, ring, and little fingers are connected together by areolar tissue and tendinous slips, as far as the palm of the hand. Opposite the first phalanges the tendons pass through the openings in the tendons of the Flexor digitorum sublimis, and are inserted into the bases of the last phalanges.

Nerve-supply.—The Flexor digitorum profundus is supplied by the eighth cervical and first thoracic nerves through the ulnar nerve and the volar interosseous branch of the median nerve.

Actions.—The Flexor digitorum profundus flexes the terminal phalanges after the Flexor digitorum sublimis has bent the middle phalanges ; it also assists in flexing the wrist.

Four small muscles, the Lumbricales, are connected with the tendons of the Flexor digitorum profundus in the palm. They will be described with the muscles of the hand (p. 526).

Fibrous sheaths of the flexor tendons.—After leaving the palm, the tendons of the Flexores digitorum sublimis et profundus lie in osseo-aponeurotic canals (fig. 589, p. 525), formed behind by the phalanges, and in front by fibrous bands which arch across the tendons, and are attached on either side to the margins of the phalanges and to the volar accessory ligaments of the interphalangeal joints. Opposite the middle of the proximal and second phalanges the bands (*digital vaginal ligaments*) are very strong, and the fibres are transverse ; but opposite the joints they are much thinner, and consist

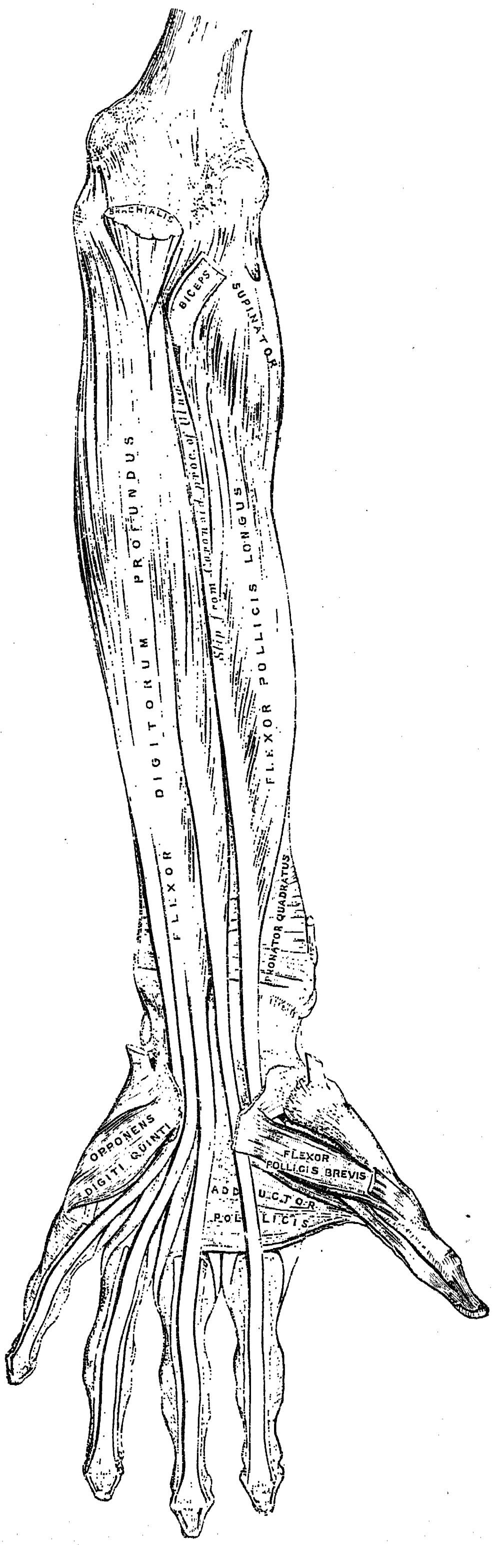
of *annular* and *cruciate* fibres. Each canal is lined by a mucous sheath, which is reflected on the contained tendons.

As the flexor tendons approach their insertions they are connected to the dorsal parts of the enclosing sheaths by triangular and thread-like bands of the mucous sheaths. These bands, termed *vincula tendinum* (fig. 578), convey minute vessels to the tendons, and are of two kinds, (*a*) vincula brevia and (*b*) vincula longa.

The *vincula brevia,* two in number in each finger, are triangular bands attached to the deep surfaces of the tendons close to their insertions; one connects the tendon of the Flexor digitorum sublimis to the front of the first interphalangeal joint and adjacent part of the first phalanx, and the other the tendon of the Flexor digitorum profundus to the front of the second interphalangeal joint and adjacent part of the second phalanx. The *vincula longa* are thread-like slips, of which two are usually attached to each tendon of the Flexor digitorum sublimis, and one to each tendon of the Flexor digitorum profundus. Those of the Flexor digitorum sublimis are connected to the slips of that tendon where these fold over the tendon of the Flexor digitorum profundus, and, passing one on either side of the latter tendon, are attached to the sheath at the lateral margins of the proximal end of the first phalanx. That of the tendon of the Flexor digitorum profundus is fixed to its tendon shortly after the latter has pierced the tendon of the Flexor digitorum sublimis. It runs upwards and backwards, perforates one of the two slips of the latter tendon, or passes between the two slips; thereafter it blends with the vinculum breve of the Flexor digitorum sublimis, and is attached to the sheath at the distal end of the first phalanx.

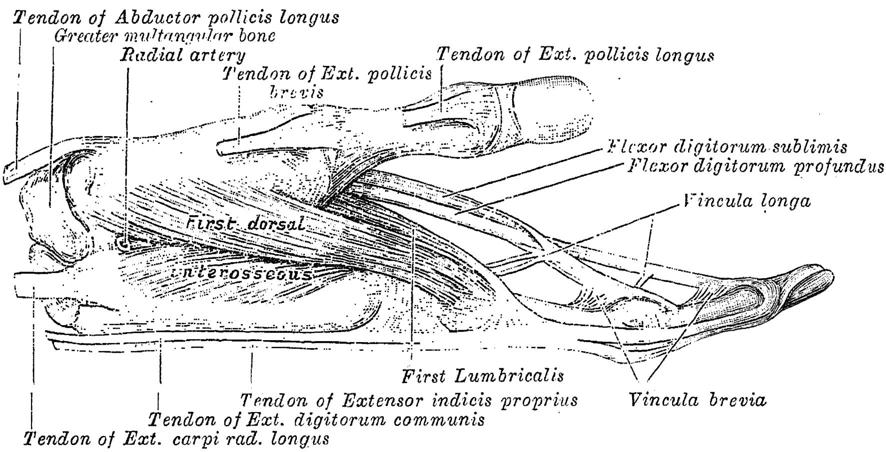
The **Flexor pollicis longus** (figs. 577, 579) is situated on the radial side of the forearm in the same plane as the Flexor digitorum profundus. It arises from the grooved volar surface of the body of the radius, extending

Fig. 577.—The left volar antibrachial muscles. Deep group.



from immediately below the tuberosity and oblique line, to within a short distance of the Pronator quadratus. It arises also from the adjacent part of the interosseous membrane, and generally by a fusiform fleshy slip from the medial border of the coronoid process below the Flexor digitorum sublimis and Pronator teres, or from the medial epicondyle of the humerus. The fibres end in a flattened tendon, which passes behind the transverse carpal ligament, is then lodged between the lateral head of the Flexor pollicis brevis and the oblique part of the Adductor pollicis, and, entering an osseo-aponeurotic canal similar to those for the flexor tendons of the fingers, is inserted into the base of the

Fig. 578.—The tendons and the vincula tendinum of the right forefinger. Lateral aspect.



distal phalanx of the thumb. The volar interosseous nerve and vessels descend on the front of the interosseous membrane between the Flexor pollicis longus and Flexor digitorum profundus.

Nerve-supply.—The Flexor pollicis longus is supplied by the eighth cervical and first thoracic nerves through the volar interosseous branch of the median nerve.

Actions.—The Flexor pollicis longus is a flexor of the phalanges of the thumb; it also acts as a flexor of the wrist.

The **Pronator quadratus** (figs. 577, 583) is a flat, quadrilateral muscle, extending across the front of the lower parts of the radius and ulna. It arises from the pronator ridge on the lower part of the volar surface of the body of the ulna; from the medial part of the volar surface of the lower one-fourth of the ulna; and from a strong aponeurosis which covers the medial one-third of the muscle. The fibres pass lateralwards and slightly downwards, to be inserted into the lower one-fourth of the lateral border and the volar surface of the body of the radius; the deeper fibres are inserted into the triangular area above the ulnar notch of the radius.

Nerve-supply.—The Pronator quadratus is supplied by the eighth cervical and first thoracic nerves through the volar interosseous branch of the median nerve.

Action.—The Pronator quadratus pronates the forearm, i.e. turns it so that the palm of the hand is directed backwards.

2. The Dorsal Antibrachial Muscles

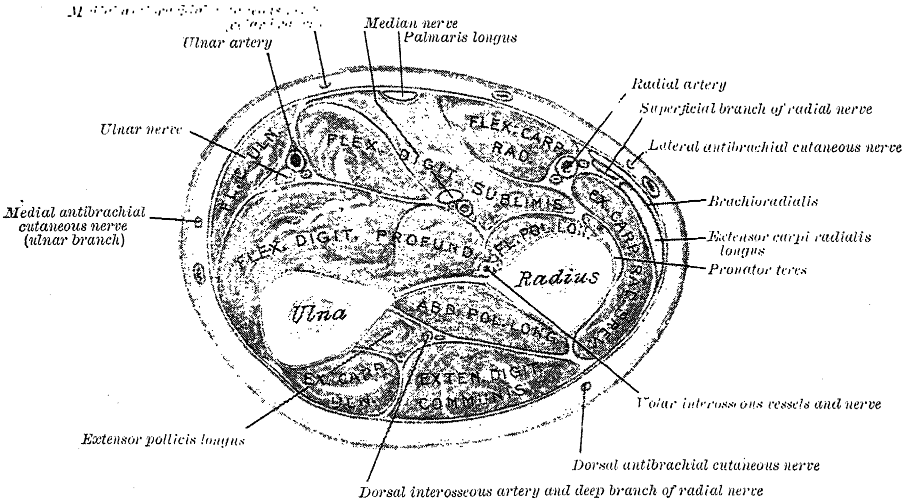
These muscles are divided for convenience of description into two groups, superficial and deep.

(a) *Superficial Group* (fig. 580)

Brachioradialis.
Extensor carpi radialis longus.
Extensor carpi radialis brevis.
Extensor digitorum communis.
Extensor digiti quinti proprius.
Extensor carpi ulnaris.
Anconæus.

The **Brachioradialis** (Supinator longus) (figs. 575, 576, 580) is the most superficial muscle on the radial side of the forearm. It arises from the upper two-thirds of the lateral supracondylar ridge of the humerus, and from the

Fig. 579.—A transverse section through the middle of the forearm.



lateral intermuscular septum. Interposed between it and the Brachialis are the radial nerve and the anastomosis between the arteria profunda brachii and the radial recurrent artery. The fibres end above the middle of the forearm in a flat tendon which is inserted into the lateral side of the base of the styloid process of the radius. The tendon is crossed at its insertion by the tendons of the Abductor pollicis longus and Extensor pollicis brevis; on its ulnar side is the radial artery.

Nerve-supply.—The Brachioradialis is supplied by the fifth and sixth cervical nerves through the radial nerve.

Action.—The Brachioradialis is a flexor of the elbow-joint, but is supplied by the nerve of the extensor muscles, i.e. the radial nerve.

The **Extensor carpi radialis longus** (figs. 576, 580) is partly covered by the Brachioradialis. It arises mainly from the lower one-third of the lateral supracondylar ridge of the humerus and from the lateral intermuscular septum, but it receives a few fibres from the common tendon of origin of the extensor muscles of the forearm. The muscle ends at the upper one-third of the forearm in a flat tendon, which runs along the lateral border of the radius, deep to the Abductor pollicis longus and Extensor pollicis brevis; it then passes under cover of the dorsal carpal ligament, where it lies on the back of

the radius in a groove immediately behind the styloid process. It is inserted into the radial side of the dorsal surface of the base of the second metacarpal bone.

Nerve-supply.—The Extensor carpi radialis longus is supplied by the sixth and seventh cervical nerves through the deep radial nerve.

Actions.—The Extensor carpi radialis longus extends the wrist and slightly abducts the hand.

The **Extensor carpi radialis brevis** (figs. 576, 579, 580) is shorter than the preceding muscle and is covered by it. It arises from the lateral epicondyle of the humerus, by a tendon common to it and the next three muscles; from the radial collateral ligament of the elbow-joint; from a strong aponeurosis which covers its surface; and from the intermuscular septa between it and the adjacent muscles. The fibres end about the middle of the forearm in a flat tendon, which closely accompanies that of the preceding muscle to the wrist; it passes beneath the Abductor pollicis longus and Extensor pollicis brevis, then under cover of the dorsal carpal ligament, and is inserted into the dorsal surface of the base of the third metacarpal bone on its radial side and distal to the styloid process. Under the dorsal carpal ligament the tendon lies on the back of the radius in a shallow groove, on the ulnar side of that which lodges the tendon of the Extensor carpi radialis longus, and separated from it by a faint ridge.

The tendons of the two preceding muscles pass through the same compartment of the dorsal carpal ligament in a single mucous sheath.

Nerve-supply.—The Extensor carpi radialis brevis is supplied by the sixth and seventh cervical nerves through the radial nerve.

Action.—The Extensor carpi radialis brevis extends the wrist.

The **Extensor digitorum communis** (figs. 576, 579, 580) arises from the lateral epicondyle of the humerus, by the common tendon; from the intermuscular septa between it and the adjacent muscles, and from the antibrachial fascia. It divides below into four tendons, which pass, together with that of the Extensor indicis proprius, through a compartment of the dorsal carpal ligament, within a mucous sheath. The tendons then diverge on the back of the hand, and are inserted into the second and third phalanges of the fingers in the following manner. Opposite the metacarpophalangeal articulation each tendon is bound by fasciculi to the collateral ligaments and serves as the dorsal ligament of this joint; after crossing the joint, it spreads into a broad aponeurosis, which covers the dorsal surface of the first phalanx and is there reinforced by the corresponding tendons of the Interossei and Lumbricalis. Opposite the first interphalangeal joint this aponeurosis divides into three slips, an intermediate and two collateral: the intermediate is inserted into the base of the second phalanx; the two collateral are continued onwards along the sides of the second phalanx, and uniting by their contiguous margins, are inserted into the dorsal surface of the ungual phalanx. As the tendons cross the interphalangeal joints, they serve as dorsal ligaments. The tendon to the index finger is accompanied by the Extensor indicis proprius, which lies on its ulnar side. On the back of the hand, the tendons to the middle, ring, and little fingers are connected by two obliquely placed bands, one from the third tendon passing distalwards and lateralwards to the second tendon, and the other passing from the fourth tendon to the third. Occasionally the second tendon is connected to the first by a thin oblique band.

Nerve-supply.—The Extensor digitorum communis is supplied by the seventh cervical nerve through the deep radial nerve.

Actions.—The Extensor digitorum communis extends the phalanges and then the wrist. Owing to its attachments to the collateral ligaments of the metacarpophalangeal joints it acts principally on the proximal phalanges, the middle and terminal phalanges being extended mainly by the Interossei and Lumbricales; it tends to separate the fingers as it extends them.

The **Extensor digiti quinti proprius** (fig. 580) is a slender muscle medial to, and usually connected with, the Extensor digitorum communis. It arises from the common extensor tendon by a thin tendinous slip, and from the intermuscular septa between it and the adjacent muscles. Its tendon runs through a compartment of the dorsal carpal ligament behind the distal

radio-ulnar joint, then divides into two as it crosses the hand, and finally joins the expansion of the Extensor digitorum communis tendon on the dorsum of the first phalanx of the fifth digit.

Nerve-supply. — The Extensor digiti quinti proprius is supplied by the seventh cervical nerve through the deep radial nerve.

Actions.—The Extensor digiti quinti proprius extends the little finger and by its continued action extends the wrist.

The **Extensor carpi ulnaris** (figs. 579, 580) arises from the lateral epicondyle of the humerus, by the common extensor tendon; from the dorsal border of the ulna by an aponeurosis in common with the Flexor carpi ulnaris and the Flexor digitorum profundus; and from the antibrachial fascia. It ends in a tendon, which runs in a groove between the head and the styloid process of the ulna, passing through a separate compartment of the dorsal carpal ligament, and is inserted into the tubercle on the ulnar side of the base of the fifth metacarpal bone.

Nerve-supply. — The Extensor carpi ulnaris is supplied by the seventh cervical nerve through the deep radial nerve.

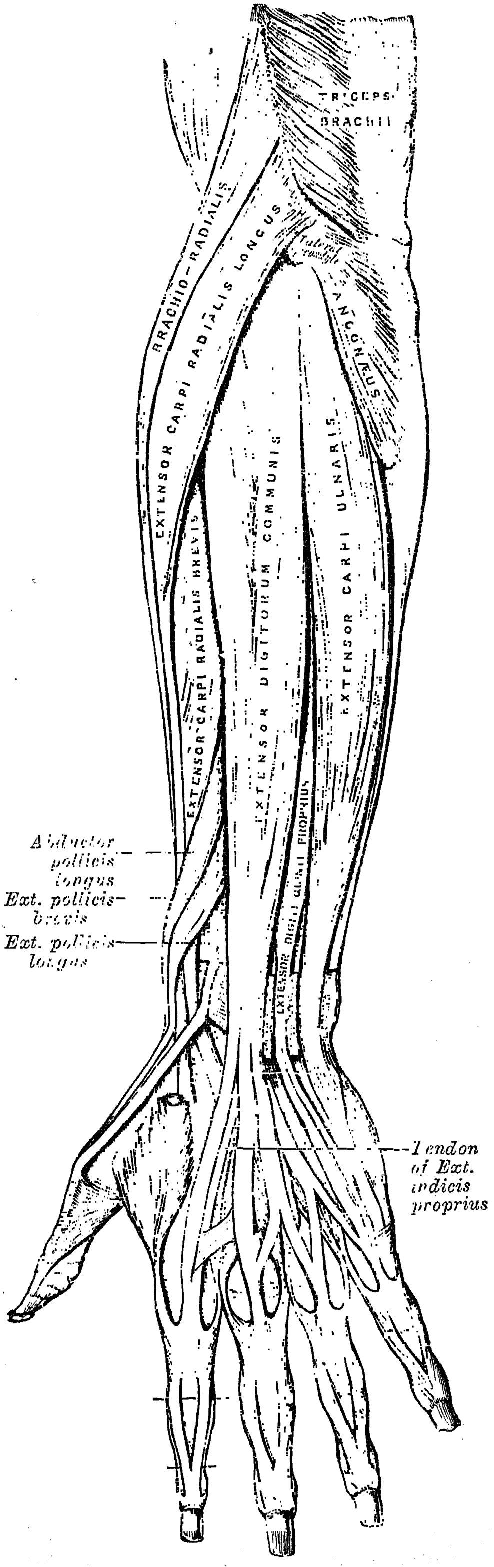
Actions.—The Extensor carpi ulnaris extends the wrist and adducts the hand.

The **Anconæus** (figs. 580, 581) is a small triangular muscle on the back of the elbow-joint, and appears to be a continuation of the Triceps brachii. It arises by a separate tendon from the posterior part of the lateral epicondyle of the humerus; its fibres diverge and are inserted into the side of the olecranon, and upper one-fourth of the dorsal surface of the body of the ulna.

Nerve-supply.—The Anconæus is supplied by the seventh and eighth cervical nerves through the radial nerve.

Action.—The Anconæus assists the Triceps in extending the elbow-joint.

Fig. 580.—The left dorsal antibrachial muscles. Superficial group.

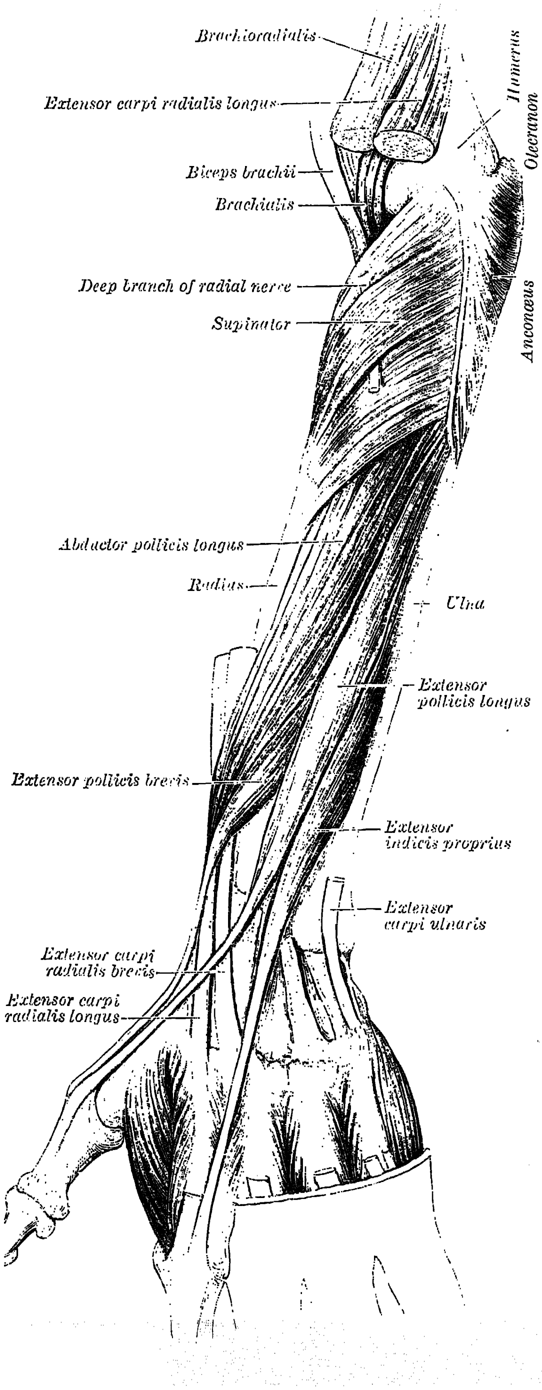


(*b*) *Deep Group* (fig. 581)

Supinator. Extensor pollicis brevis.
Abductor pollicis longus. Extensor pollicis longus.
Extensor indicis proprius.

The **Supinator** (Supinator brevis) (figs. 576, 581, 582) curves round the upper one-third of the radius. It consists of fibres arranged in two planes, between which the deep branch of the radial nerve passes. The two planes arise in common—the superficial one by tendinous and the deeper by muscular fibres—from the lateral epicondyle of the humerus; from the radial collateral ligament of the elbow-joint, and the annular ligament of the proximal radio-ulnar joint; from the ridge on the ulna, which runs obliquely downwards from the dorsal end of the radial notch; from the distal part of the triangular depression below the notch; and from a tendinous expansion which covers the surface of the muscle. The superficial fibres surround the upper part of the radius, and are inserted into the lateral edge of the radial tuberosity and the oblique line of the radius as low down as the insertion of the Pronator teres. The upper fibres of the deeper plane form a sling-like fasciculus, which encircles the neck of the radius above the tuberosity and is attached to the back part of its medial surface: the greater part of this portion of the muscle is inserted into the dorsal and lateral surfaces of the body of the radius, between the oblique line and the head of the bone.

FIG. 581.—The left dorsal antibrachial muscles. Deep group.



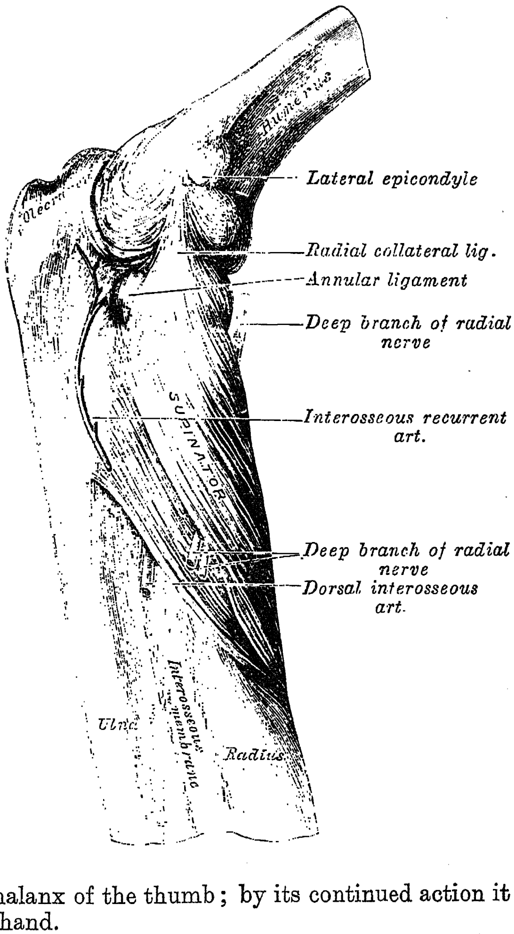
Nerve-supply.—The Supinator is supplied by the fifth and sixth cervical nerves through the deep radial nerve.

Actions. — The Supinator rotates the radius so as to turn the palm of the hand forwards.

The **Abductor pollicis longus** (Extensor ossis metacarpi pollicis) (figs. 579, 580, 581) lies immediately below the Supinator and is sometimes united with it. It arises from the lateral part of the dorsal surface of the body of the ulna below the insertion of the Anconæus, from the

interosseous membrane, and from the middle one-third of the dorsal surface of the body of the radius. Passing obliquely downwards and lateralwards, it ends in a tendon (frequently two tendons), which runs through a groove on the lateral side of the lower end of the radius, accompanied by the tendon of the Extensor pollicis brevis, and is inserted into the radial side of the base of the first metacarpal bone. It occasionally gives off two slips near its insertion: one to the greater multangular bone, and the other to blend with the origin of the Abductor pollicis brevis.

Fig. 582.—The right Supinator. Dorsolateral aspect.



Nerve-supply.—The Abductor pollicis longus is supplied by the seventh cervical nerve through the deep radial nerve.

Actions.—The Abductor pollicis longus abducts the thumb and hand. In the absence through paralysis of the two flexors of the wrist-joint the muscle may flex the hand on the wrist with some considerable force (F. Wood Jones).*

The **Extensor pollicis brevis** (figs. 580, 581) lies on the medial side of, and is closely connected with, the Abductor pollicis longus. It arises from the dorsal surface of the body of the radius below that muscle, and from the interosseous membrane. Its direction is similar to that of the Abductor pollicis longus, its tendon passing through the same groove on the lateral side of the lower end of the radius, to be inserted into the dorsal surface of the base of the first phalanx of the thumb.

Nerve-supply.—The Extensor pollicis brevis is supplied by the seventh cervical nerve through the deep radial nerve.

Actions.—The Extensor pollicis brevis extends the proximal phalanx of the thumb; by its continued action it extends the wrist, and abducts the hand.

The **Extensor pollicis longus** (figs. 580, 581) is larger than the preceding muscle, the origin of which it partly covers. It arises from the lateral part of the middle one-third of the dorsal surface of the body of the ulna below the origin of the Abductor pollicis longus, and from the interosseous membrane. It ends in a tendon, which passes through a compartment of the dorsal carpal ligament, lying in a narrow, oblique groove on the back of the lower end of the radius. It then crosses obliquely the tendons of the Extensores carpi radiales longus et brevis, and is separated from the Extensor brevis pollicis by a triangular interval, in which the radial artery is found; it is inserted into the base of the last phalanx of the thumb. The radial artery is crossed by the tendons of the Abductor pollicis longus and of the Extensores pollicis longus et brevis.

Nerve-supply.—The Extensor pollicis longus is supplied by the seventh cervical nerve through the deep radial nerve.

Actions.—The Extensor pollicis longus extends the terminal phalanx of the thumb; by its continued action it extends the wrist, and abducts the hand.

* 'The principles of Anatomy as seen in the hand,' 1920.

The **Extensor indicis proprius** (fig. 581) is a narrow, elongated muscle, medial to, and parallel with, the preceding. It arises from the dorsal surface of the body of the ulna below the origin of the Extensor pollicis longus, and from the interosseous membrane. Its tendon passes under cover of the dorsal carpal ligament in the compartment which transmits the tendons of the Extensor digitorum communis; opposite the head of the second metacarpal bone it joins the ulnar side of the tendon of the Extensor digitorum communis which runs to the index finger.

Nerve-supply.—The Extensor indicis proprius is supplied by the seventh cervical nerve through the deep radial nerve.

Actions.—The Extensor indicis proprius extends the index finger, and assists in extending the wrist.

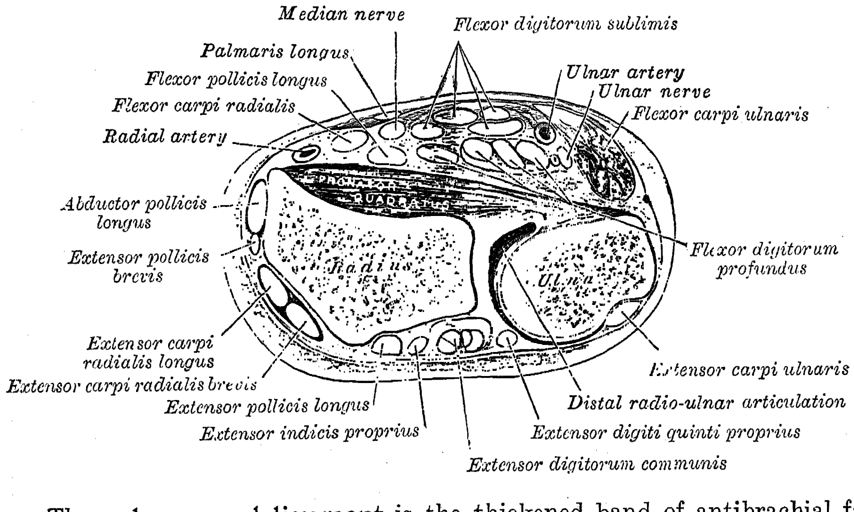
Applied Anatomy.—The tendons of the Abductor longus and extensors of the thumb are liable to become strained, and their sheaths inflamed (*tenosynovitis*) after excessive exercise, producing a sausage-shaped swelling along the course of the tendons and giving a peculiar grating sensation to the touch when the muscles are put in action.

Paralysis of the extensor muscles of the wrists and fingers resulting in 'wrist-drop' is common in lead poisoning in painters. The different extensor muscles are affected unequally as a rule. Thus the thumb, or index, or little finger may be but slightly implicated, and recover rapidly while the extensors of the other fingers or wrist remain powerless; and some of the flexor muscles of the fingers may become paretic. This apparently selective action of the lead in cases of lead poisoning depends in reality upon occupational over use of the affected muscles or groups of muscles.

VI. The Muscles of the Hand

The muscles of the hand are subdivided into three groups: 1, those of the **thumb**, which occupy the radial side and produce the *thenar* eminence; 2, those of the little finger, which occupy the ulnar side and give rise to the *hypothenar* eminence; 3, those in the middle of the palm and between the metacarpal bones.

Fig. 583.—A transverse section through the distal ends of the left radius and ulna. Superior aspect.



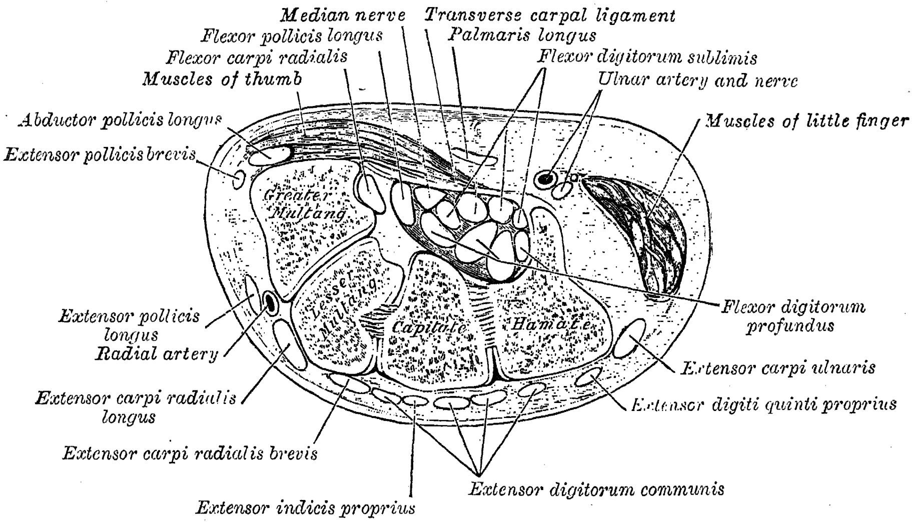
The **volar carpal ligament** is the thickened band of antibrachial fascia which extends from the radius to the ulna in front of the flexor tendons as they approach the wrist.

The **transverse carpal ligament** (anterior annular ligament) (figs. 584, 585) is a strong, fibrous band, which crosses the front of the carpus, and converts the concavity formed by the volar surfaces of the carpal bones into a tunnel, through which the flexor tendons of the digits and the median nerve pass. It is attached, medially, to the pisiform bone and to the hamulus of the hamate bone; laterally, it splits into two laminæ, a superficial attached to the tubercles

of the navicular and greater multangular bones, and a deep to the posterior lip of the groove on the latter bone ; the two laminæ form with the groove on the greater multangular bone a tunnel which is traversed by a mucous sheath containing the tendon of the Flexor carpi radialis. The ligament is continuous, above, with the volar carpal ligament ; and below, with the palmar aponeurosis. It is crossed superficially by the ulnar vessels and nerve, and the cutaneous branches of the median and ulnar nerves. On its volar surface the tendons of the Palmaris longus and Flexor carpi ulnaris are partly inserted ; below, it gives origin to the short muscles of the thumb and little finger.

The **mucous sheaths of the tendons on the front of the wrist.**—Two mucous sheaths envelop the flexor tendons as they traverse the carpal tunnel, one for the Flexores digitorum sublimis et profundus, the other for the Flexor pollicis longus (fig. 585). These sheaths extend into the forearm for about 2·5 cm. above the transverse carpal ligament, and occasionally communicate with each other behind the ligament. The sheath of the Flexores digitorum

FIG. 584.—A transverse section through the left wrist. Superior aspect.



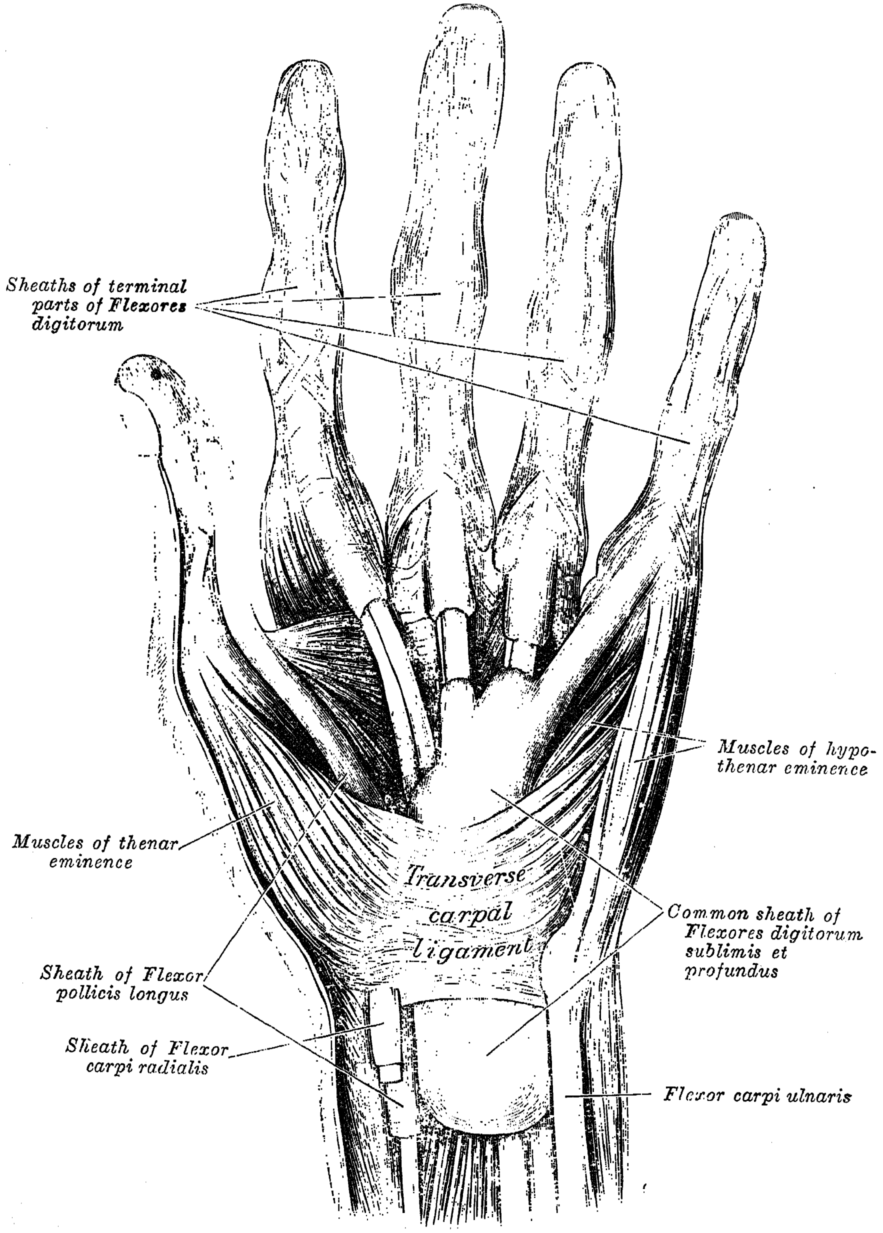
tendons reaches about halfway along the metacarpal bones, where it ends in blind diverticula around the tendons to the index, middle, and ring fingers. It is prolonged on the tendons to the little finger and usually communicates with the digital mucous sheath of these tendons. The sheath of the tendon of the Flexor pollicis longus is continued along the thumb as far as the insertion of the tendon. The mucous sheaths enveloping the terminal parts of the tendons of the Flexores digitorum have been described (p. 510).

The **dorsal carpal ligament** (posterior annular ligament) (fig. 586) is a strong, fibrous band, extending obliquely across the back of the wrist, and consisting of part of the antibrachial fascia, strengthened by the addition of some transverse fibres. It is attached, medially, to the styloid process of the ulna and to the triquetral and pisiform bones; laterally, to the lateral margin of the radius ; and, in its passage across the wrist, to the ridges on the dorsal surface of the radius.

The **mucous sheaths of the tendons on the back of the wrist.**—Beneath the dorsal carpal ligament there are six compartments for the passage of the extensor tendons, each compartment containing a mucous sheath. One is found in each of the following positions (fig. 586) : (1) on the lateral side of the styloid process, for the tendons of the Abductor pollicis longus and Extensor pollicis brevis ; (2) behind the styloid process, for the tendons of the Extensores carpi radiales longus et brevis ; (3) about the middle of the dorsal surface of the radius, for the tendon of the Extensor pollicis longus ; (4) to the medial side of the latter, for the tendons of the Extensor digitorum

communis and Extensor indicis proprius ; (5) opposite the interval between the radius and ulna, for the Extensor digiti quinti proprius ; (6) between the head and the styloid process of the ulna, for the tendon of the Extensor carpi ulnaris. The sheaths of the tendons of the Abductor pollicis longus, Extensor

Fig. 585.—The mucous sheaths of the tendons on the front of the left wrist and hand. (From a specimen prepared by J. C. B. Grant.)

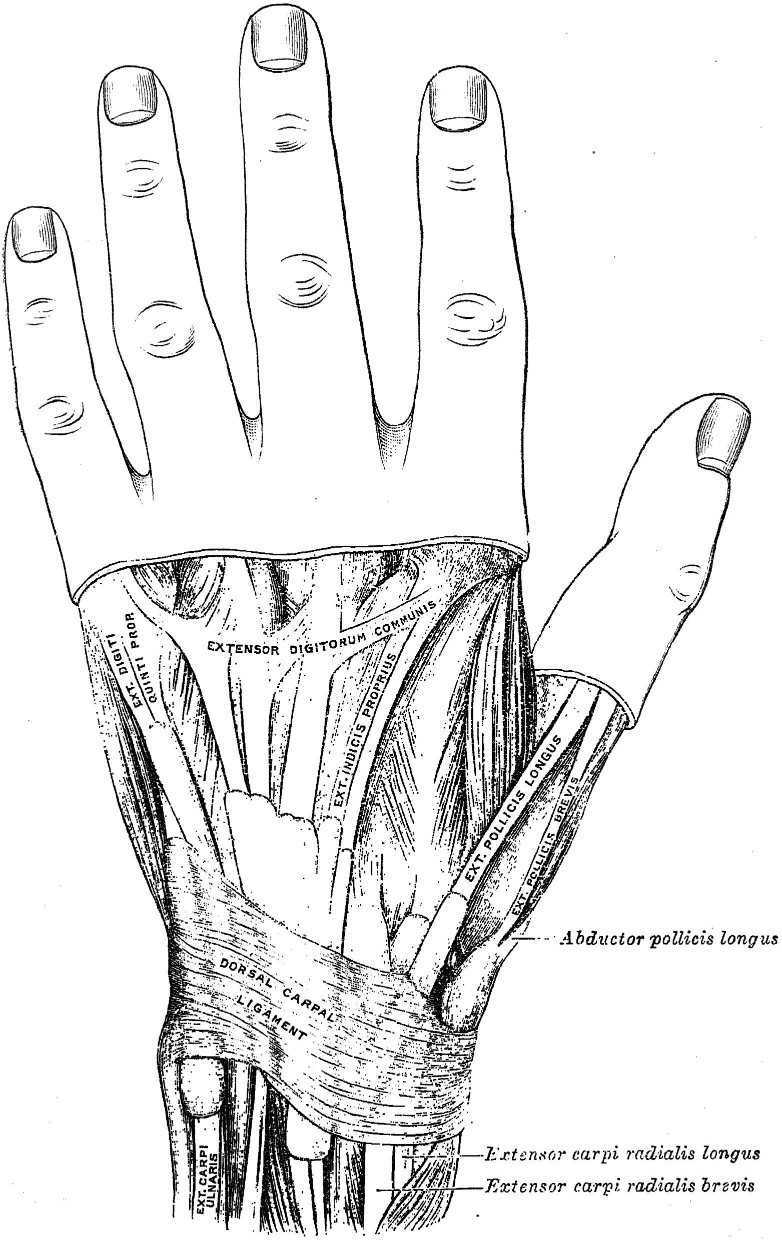


pollicis brevis, Extensores carpi radialis, and Extensor carpi ulnaris stop immediately proximal to the bases of the metacarpal bones, while those of the Extensor digitorum communis, Extensor indicis proprius, and Extensor digiti quinti proprius are prolonged to the junction of the proximal with the intermediate one-third of the metacarpus.

The **palmar aponeurosis** (fig. 587) invests the muscles of the palm, and consists of central, lateral, and medial portions.

The *central portion* occupies the middle of the palm, is triangular in shape, and of great strength and thickness. Its apex is continuous with the distal

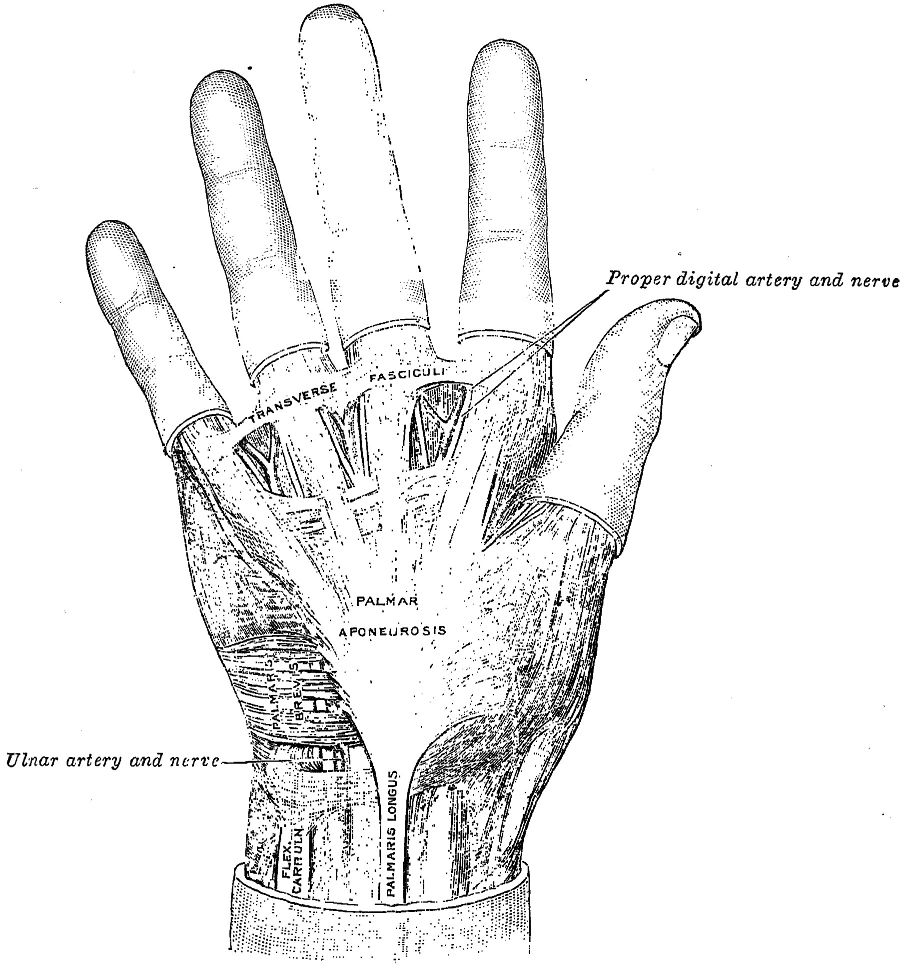
Fig. 586.—The mucous sheaths of the tendons on the back of the left wrist. (From a specimen prepared by J. C. B. Grant.)



margin of the transverse carpal ligament, and gives insertion to the expanded tendon of the Palmaris longus. Its base divides into four slips, one for each finger. The slips give off superficial fibres to the skin of the palm and fingers; those to the palm joining the skin at the furrow corresponding to the metacarpophalangeal articulations, and those to the fingers passing into the skin at the transverse folds at the roots of the fingers. The deeper part of each

slip subdivides into two processes, which are inserted into the fibrous sheaths of the flexor tendons; from the sides of these processes offsets are attached to the transverse metacarpal ligament. By this arrangement short channels are formed on the front of the heads of the metacarpal bones; through these the flexor tendons pass. The intervals between the four slips transmit the digital vessels and nerves, and the tendons of the Lumbricales. At the points of division into the slips mentioned, numerous strong, transverse fibres bind

FIG. 587.—The right palmar aponeurosis.



the separate processes together. The central part of the palmar aponeurosis is intimately bound to the skin by dense fibro-areolar tissue, and gives origin by its medial margin to the Palmaris brevis. It covers the superficial volar arch, the tendons of the Flexores digitorum, the terminal part of the median nerve, and the superficial part of the ulnar nerve; on either side it gives off a septum which separates the intermediate from the lateral and medial groups of muscles.

The *lateral and medial portions* of the palmar aponeurosis are thin, fibrous layers, which cover the muscles of the ball of the thumb, and the short muscles of the little finger respectively; they are continuous with the central portion and with the fascia on the dorsum of the hand.

The **superficial transverse fasciculi** form a thin band (fig. 587) which stretches across the roots of the fingers, and is attached to the skin of the

clefts, and medially to the fifth metacarpal bone, forming a sort of rudimentary web. The digital vessels and nerves pass beneath these fasciculi.

Applied Anatomy.—The palmar aponeurosis is liable to undergo contraction, producing a very inconvenient deformity known as 'Dupuytren's contraction.' The ring and little fingers are most frequently implicated, but the others may also be involved. The proximal phalanx is flexed and cannot be straightened, and the two distal phalanges become similarly flexed as the disease advances.

Owing to their constant exposure to injury and septic influences, the fingers are very liable to become the seat of serious inflammatory mischief. In some cases, the inflammation may involve the theca of the flexor tendons, and a *thecal paronychia* may result. The inflammation then rapidly spreads up the sheath; but the extent will depend upon the particular digit involved. From the description of the flexor sheaths given above, it will be evident that inflammation of the mucous sheaths of the thumb and little finger may prove a far more formidable affection than that of the other three digits, because the sheaths of these two digits communicate with the large mucous sheath which surrounds the flexor tendons (p. 519), and the inflammation may extend into the palm of the hand and behind the transverse carpal ligament into the forearm.

In order to relieve these conditions, free and early incisions are necessary, and must be made with discrimination, in order to avoid wounding important structures. In the pulp of the finger—i.e. over the distal phalanx—the incision should be made in the middle line and down to the bone. In the rest of the finger, the incision should be made in the middle line over the phalanges, and not over the interphalangeal joints. In the palm of the hand, incisions may be made either on the distal or proximal side of the superficial volar arch. On the distal side the incisions should be made over the metacarpal bones, preferably those of the index and middle finger. On the proximal side, the safest line of incision is along the radial side of the hypothenar eminence, between the ulnar artery and nerve medially, and the median nerve laterally. When suppuration has extended under the transverse carpal ligament, and incisions are required in the forearm, the positions in which they should be made are over the tendons of the Flexor digitorum sublimis, between the median nerve and the ulnar artery, and over the tendon of the Flexor pollicis longus, between the radial artery and the tendon of the Flexor carpi radialis.

Chronic inflammation of the common flexor sheath is occasionally met with, constituting a disease known as *compound palmar ganglion*; it presents an hour-glass outline, with a swelling in front of the wrist and another in the palm of the hand, and a constriction, corresponding to the transverse carpal ligament, between the two. The fluid can be forced from the one swelling to the other under the ligament, and when this is done, a creaking sensation is sometimes perceived, from the presence of 'melon-seed' bodies in the interior of the ganglion.

1. The Lateral Volar Muscles (figs. 588, 589)

Abductor pollicis brevis.	Flexor pollicis brevis.
Opponens pollicis.	Adductor pollicis.

The **Abductor pollicis brevis** (fig. 589) is a thin, subcutaneous muscle; it arises from the transverse carpal ligament, the tuberosity of the navicular bone, and the ridge of the greater multangular bone. It is inserted by a thin, flat tendon into the radial side of the base of the first phalanx of the thumb and the capsule of the metacarpophalangeal articulation.

Nerve-supply.—The Abductor pollicis brevis is supplied by the sixth and seventh cervical nerves through the median nerve.

Actions.—The Abductor pollicis brevis draws the thumb forwards in a plane at right angles to the palm of the hand and abducts the proximal phalanx.

The **Opponens pollicis** (figs. 588, 589) is placed beneath the Abductor pollicis brevis. It arises from the ridge on the greater multangular bone, and from the transverse carpal ligament, and is inserted into the whole of the anterolateral surface of the metacarpal bone of the thumb on its radial side.

Nerve-supply.—The Opponens pollicis is supplied by the sixth and seventh cervical nerves through the median nerve.

Actions.—The Opponens pollicis flexes the metacarpal bone of the thumb, i.e. bends it medialwards across the palm of the hand.

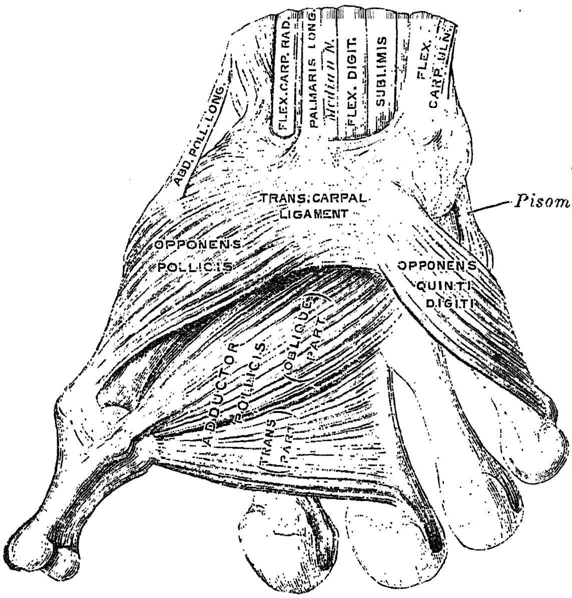
The **Flexor pollicis brevis** (fig. 589) consists of two portions, superficial and deep. The *superficial portion* arises from the lower border of the transverse carpal ligament and the lower part of the ridge on the greater multangular

bone; it passes along the radial side of the tendon of the Flexor pollicis longus, and is inserted into the radial side of the base of the first phalanx of the thumb; in its tendon of insertion there is a sesamoid bone. The *deep portion* is very small. It arises from the ulnar side of the base of the first metacarpal bone and is inserted into the ulnar side of the base of the first phalanx with the oblique part of the Adductor pollicis; it is sometimes described as the *first volar interosseous* muscle.

Nerve-supply.—The superficial portion of the Flexor pollicis brevis is supplied by the sixth and seventh cervical nerves through the median nerve; the deep portion by the eighth cervical nerve through the ulnar nerve.

Actions.—The Flexor pollicis brevis flexes and adducts the proximal phalanx of the thumb.

FIG. 588.—The right Opponens pollicis, Adductor pollicis and Opponens digiti quinti.



The **Adductor pollicis** (fig. 588) consists of an oblique and a transverse part. The *oblique part* arises from the capitate and lesser multangular bones, the bases of the second and third metacarpal bones, the intercarpal ligaments, and the sheath of the tendon of the Flexor carpi radialis. Most of its fibres converge to a tendon, which, uniting with the tendons of the deep portion of the Flexor pollicis brevis and the transverse part of the Adductor, is inserted into the ulnar side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon. A considerable fasciculus, however, passes beneath the tendon of the Flexor pollicis longus and joins the superficial portion of the Flexor pollicis brevis and the Abductor pollicis brevis. The *transverse part* (fig. 588) is the most deeply seated of this group of muscles. It is of a triangular form, and arises from the distal two-thirds of the volar surface of the third metacarpal bone; the fibres converge, to be inserted with the oblique part of the muscle and with the deep part of the Flexor pollicis brevis into the ulnar side of the base of the first phalanx of the thumb.

Nerve-supply.—The Adductor pollicis is supplied by the eighth cervical nerve through the ulnar nerve.

Action.—The Adductor pollicis approximates the thumb to the palm of the hand.

in which the cephalic vein and deltoid branch of the thoraco-acromial artery lie. Its *lower border* forms the anterior fold of the axilla; it is separated from the Latissimus dorsi by a considerable interval at the medial wall of the axilla, but the two muscles gradually converge towards the lateral wall of the space.

Nerve-supply.—The Pectoralis major is supplied by the medial and lateral anterior thoracic nerves; through these it receives filaments from all the nerves entering into the formation of the brachial plexus; the fibres for the clavicular part of the muscle are derived from the fifth and sixth cervical nerves.

Actions.—The Pectoralis major adducts the arm. If the arm be flexed the muscle draws it forwards across the front of the chest and rotates it inwards. When the arms are fixed the Pectorales majores draw the trunk upwards and forwards as in climbing.

The **coracoclavicular fascia** (costocoracoid membrane) is a strong fascia situated under cover of the clavicular portion of the Pectoralis major. It occupies the interval between the Pectoralis minor and Subclavius, and protects the axillary vessels and nerves. Traced upwards, it splits to enclose the Subclavius, and is attached to the clavicle, in front of and behind the muscle; the layer behind the muscle fuses with the fascia colli and with the sheath of the axillary vessels. Medially, the coracoclavicular fascia blends with the fascia covering the first two intercostal spaces, and is attached also to the first rib medial to the origin of the Subclavius. Laterally, it is thick and dense, and is attached to the coracoid process. The portion extending from the first rib to the coracoid process is often stronger than the rest, and is sometimes called the *costocoracoid ligament.* Below this, the fascia is thin; it splits to ensheathe the Pectoralis minor; and from the lower border of this muscle is continued downwards to join the axillary fascia, and lateralwards to unite with the fascia covering the short head of the Biceps brachii. The coraco-clavicular fascia is pierced by the cephalic vein, thoraco-acromial artery and vein, and lateral anterior thoracic nerve.

The **Pectoralis minor** (fig. 570) is a thin, triangular muscle, situated at the upper part of the thorax, deep to the Pectoralis major. It arises from the upper margins and outer surfaces of the third, fourth, and fifth ribs, near their cartilages, and from the aponeuroses covering the Intercostales externi; the fibres pass upwards and lateralwards, and converge to form a flat tendon, which is inserted into the medial border and upper surface of the coracoid process of the scapula. Sometimes a part or the whole of the tendon is continued over the coracoid process and through the coraco-acromial ligament; when this occurs the tendon blends with the coracohumeral ligament and thus gains an attachment to the humerus.

Relations.—Its *anterior surface* is in relation with the Pectoralis major, the lateral anterior thoracic nerve, and the pectoral branch of the thoraco-acromial artery; its *posterior surface,* with the ribs, Intercostales externi, Serratus anterior, the axillary space, and the axillary vessels and brachial plexus of nerves. Its *upper border* is separated from the clavicle by a narrow triangular interval occupied by the coracoclavicular fascia, behind which are the axillary vessels and nerves. Running parallel with the *lower border* of the muscle is the lateral thoracic artery; piercing and partly supplying the muscle is the medial anterior thoracic nerve.

Nerve-supply.—The Pectoralis minor is supplied by the seventh and eighth cervical and first thoracic nerves through the anterior thoracic nerves.

Actions.—The Pectoralis minor depresses the scapula and rotates it by drawing the lateral angle downwards and forwards. When the arm is fixed it assists in elevating the ribs in forced inspiration.

The **Subclavius** (fig. 570) is a small triangular muscle, placed between the clavicle and first rib. It arises by a short, thick tendon from the junction of the first rib and first costal cartilage, in front of the costoclavicular ligament; the fleshy fibres proceed obliquely upwards and lateralwards, to be inserted into the groove on the under surface of the clavicle between the costoclavicular and coracoclavicular ligaments.

Relations.—Its *posterior surface* is separated from the first rib by the subclavian vessels and brachial plexus of nerves. Its *anterior surface* is separated from the Pectoralis major by the coracoclavicular fascia, which, with the clavicle, forms an osseo-fibrous sheath for the muscle.

Action.—The Palmaris brevis corrugates the skin on the ulnar side of the palm of the hand.

The **Abductor digiti quinti** (fig. 589) is situated on the ulnar border of the palm of the hand. It arises from the pisiform bone and from the tendon of the Flexor carpi ulnaris, and ends in a flat tendon which divides into two slips; one is inserted into the ulnar side of the base of the first phalanx of the little finger, the other into the ulnar border of the aponeurosis of the Extensor digiti quinti proprius.

Nerve-supply.—The Abductor digiti quinti is supplied by the eighth cervical nerve through the ulnar nerve.

Action.—The Abductor digiti quinti abducts the proximal phalanx of the little finger.

The **Flexor digiti quinti brevis** (fig. 589) lies on the radial side of the preceding muscle. It arises from the convex surface of the hamulus of the hamate bone and the volar surface of the transverse carpal ligament, and is inserted into the ulnar side of the base of the first phalanx of the little finger. It is separated from the Abductor by the deep volar branches of the ulnar artery and nerve. This muscle is sometimes wanting; the Abductor is then, usually, of large size.

Nerve-supply.—The Flexor digiti quinti brevis is supplied by the eighth cervical nerve through the ulnar nerve.

Actions.—The Flexor digiti quinti brevis flexes and abducts the proximal phalanx of the little finger.

The **Opponens digiti quinti** (fig. 588) is of a triangular form, and placed under cover of the Flexor and Abductor. It arises from the convexity of the hamulus of the hamate bone, and contiguous portion of the transverse carpal ligament; it is inserted into the whole length of the ulnar margin of the fifth metacarpal bone.

Nerve-supply.—The Opponens digiti quinti is supplied by the eighth cervical nerve through the ulnar nerve.

Action.—The Opponens digiti quinti draws forwards the fifth metacarpal bone, so as to deepen the hollow of the palm.

3. The Intermediate Muscles

Lumbricales. Interossei.

The **Lumbricales** (fig. 589) are four small fleshy fasciculi, which take origin from the tendons of the Flexor digitorum profundus. The first and second arise from the radial sides and volar surfaces of the tendons of the index and middle fingers respectively; the third, from the contiguous sides of the tendons of the middle and ring fingers; and the fourth, from the contiguous sides of the tendons of the ring and little fingers. Each passes to the radial side of the corresponding finger, and opposite the metacarpophalangeal articulation is inserted into the tendinous expansion of the Extensor digitorum communis covering the dorsal surface of the finger.

Nerve-supply.—The first and second Lumbricales are supplied by the sixth and seventh cervical nerves through the median nerve; the third and fourth Lumbricales by the eighth cervical through the ulnar nerve. The third Lumbricalis frequently receives a twig from the median nerve.

Actions.—The Lumbricales flex the proximal and extend the middle and terminal phalanges.

The **Interossei** occupy the intervals between the metacarpal bones, and are divided into a dorsal and a volar set.

The **Interossei dorsales** (fig. 590), four in number, are bipennate muscles, each arising by two heads from the adjacent sides of the metacarpal bones, but more extensively from the metacarpal bone of the finger into which the muscle is inserted. They are inserted into the bases of the first phalanges and into the aponeuroses of the tendons of the Extensor digitorum communis. Between the double origin of each of these muscles is a narrow triangular interval; through the first of these intervals the radial artery passes; through each of the others a perforating branch from the deep volar arch is transmitted. The *first* or *Abductor indicis* is larger than the others; it is inserted into the

radial side of the index finger. The *second* and *third* are inserted into the middle finger, the former into its radial, the latter into its ulnar side. The *fourth* is inserted into the ulnar side of the ring finger.

The **Interossei volares** (fig. 591), three in number, are smaller than the Interossei dorsales, and are placed upon the volar surfaces of the metacarpal bones, rather than between them. Each arises from the entire length of the metacarpal bone of one finger, and is inserted into the side of the base of the first phalanx of the same finger, and into the aponeurosis of the Extensor digitorum communis tendon.

Fig. 590.—The Interossei dorsales of the left hand. Dorsal aspect.

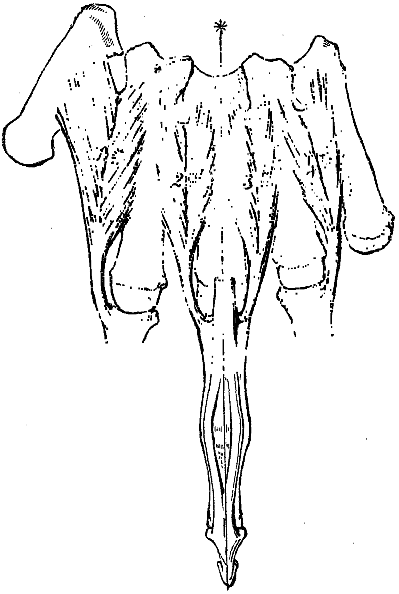
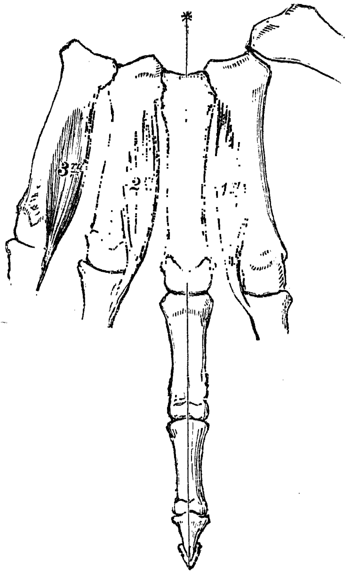


Fig. 591.—The Interossei volares of the left hand. Volar aspect.



The *first* arises from the ulnar side of the second metacarpal bone, and is inserted into the same side of the first phalanx of the index finger. The *second* arises from the radial side of the fourth metacarpal bone, and is inserted into the same side of the ring finger. The *third* arises from the radial side of the fifth metacarpal bone, and is inserted into the same side of the little finger. From this account it may be seen that each finger is provided with a pair of Interossei, with the exception of the little finger, in which the Abductor digiti quinti takes the place of one of the pair.

As already mentioned (p. 524), the deep head of Flexor pollicis brevis is sometimes described as the first volar interosseous muscle.

Nerve-supply.—The Interossei dorsales et volares are supplied by the eighth cervical nerve through the ulnar nerve.

Actions.—The Interossei dorsales abduct the fingers from an imaginary line drawn longitudinally through the centre of the middle finger; and the Interossei volares adduct the fingers to that line. The Interossei, in conjunction with the Lumbricales, flex the first phalanges, and, in consequence of their insertions into the expansions of the Extensor tendons, extend the second and third phalanges.

Applied Anatomy.—In considering the actions of the various muscles upon fractures of the upper extremity, the most common forms of injury have been selected both for illustration and description.

Fracture of the *middle of the clavicle* (fig. 592) is usually attended with considerable displacement of the lateral fragment, which is drawn downwards and medialwards, and at the same time rotated, so that its lateral end is carried forwards and its medial end backwards.

The displacement is produced as follows: the lateral fragment is drawn downwards by the weight of the arm, the Trapezius not being able to support this. It is drawn medialwards by the Subclavius and Pectoralis minor, possibly assisted by the Pectoralis major and Latissimus dorsi; and is rotated on an axis drawn through its own centre by the Serratus anterior, which causes the scapula to rotate on the wall of the chest, and carries the acromion and the end of the lateral fragment of the clavicle forwards, and so carries the medial end of the lateral portion backwards. Lying on the back keeps the scapula in position and allows gravity to rectify the displacement of the lateral fragment.

In fracture of the *acromial end of the clavicle*, between the conoid and trapezoid ligaments, only slight displacement occurs, as these ligaments, from their oblique insertion, serve to hold both portions of the bone in apposition. Fracture, also, of the *sternal end*, medial to the costoclavicular ligament, is attended with only slight displacement, this ligament serving to retain the fragments in close apposition.

Fig. 592.—A fracture of the middle of the clavicle.

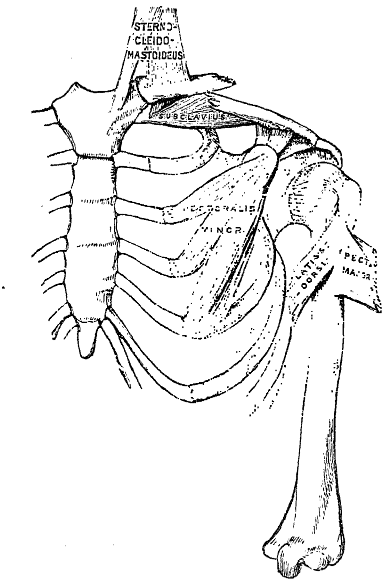
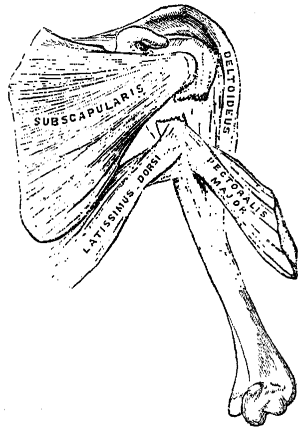


Fig. 593.—A fracture of the surgical neck of the humerus.



Fracture of the *acromion* is usually caused by violence applied to the upper and lateral part of the shoulder. There is great displacement; the lateral fragment being drawn downwards by the weight of the arm, and rotated forwards and medialwards, so that it forms a right angle with the rest of the bone.

Fracture of the *surgical neck of the humerus* (fig. 593) is very common. It is attended with considerable displacement, and its appearances correspond somewhat with those of dislocation of the head of the humerus into the axilla. The upper fragment remains in its place under the coraco-acromial ligament; the lower is drawn medialwards by the Pectoralis major, Latissimus dorsi, and Teres major; and the humerus is thrown obliquely from the side of the chest by the Deltoideus, and occasionally elevated so as to cause the upper end of the lower fragment to project beneath and in front of the coracoid process.

In fracture of the *body of the humerus* below the insertion of the Pectoralis major, Latissimus dorsi, and Teres major, and above the insertion of the Deltoideus, there is also considerable deformity, the upper fragment being drawn medialwards by the first-mentioned muscles, and the lower fragment upwards and lateralwards by the Deltoideus. Shortening of the limb results, with a considerable prominence at the seat of fracture, from the fractured ends of the bone riding over one another, especially if the fracture take place in an oblique direction.

In fracture of the *body of the humerus* immediately below the insertion of the Deltoideus the amount of deformity depends greatly upon the direction of the fracture. If it occur in a transverse direction, only slight displacement takes place, the upper fragment being drawn a little forwards; but in oblique fracture, the combined actions of the Biceps brachii and Brachialis in front and the Triceps brachii behind draw upwards the lower fragment, causing it to glide over the upper, either backwards or forwards,

according to the direction of the fracture. It is in this fracture that the chest-wall is found to make the best splint for the medial side of the bone.

Fracture of the *humerus* immediately above the condyles (fig. 594) deserves very attentive consideration, as the general appearances correspond somewhat with those produced by separation of the epiphysis of the humerus, and with those of dislocation of the radius and ulna backwards. If the direction of the fracture is oblique, from above, downwards and

FIG. 594.—A fracture of the humerus above the condyles.

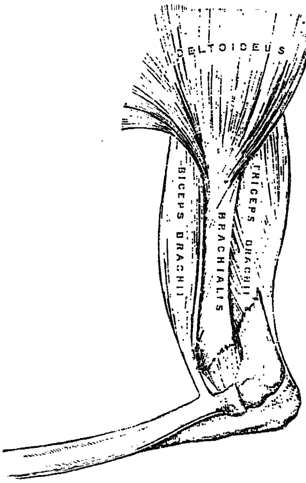
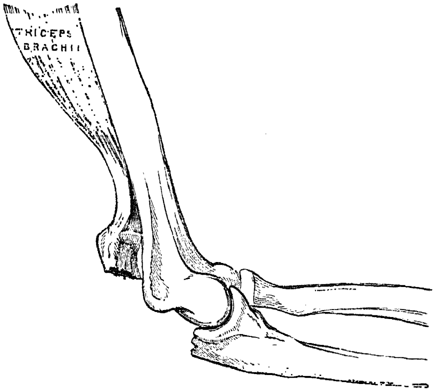


FIG. 595.—A fracture of the olecranon.

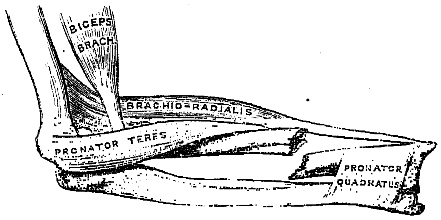


forwards, the lower fragment is drawn upwards by the Brachialis and Biceps brachii in front, and the Triceps brachii behind; and at the same time is drawn backwards behind the upper fragment by the Triceps brachii. This fracture may be diagnosed from dislocation, by the increased mobility, the existence of crepitus, and the fact that the deformity is remedied by extension, but is reproduced on the discontinuance of it. The age of the patient is of importance in distinguishing this form of injury from separation of the epiphysis. In some cases where the injury has been produced by falls on the elbow, the lower fragment is drawn upwards and forwards, causing a considerable prominence in front, the upper fragment projecting backwards beneath the tendon of the Triceps brachii. In the treatment of fractures of the lower end of the humerus, acute flexion of the elbow-joint gives the best results; this is especially so in children.

In fracture of the *olecranon* (fig. 595) the detached fragment is displaced upwards from 1 cm. to 5 cm. by the action of the Triceps brachii; the prominence of the elbow is consequently lost, and a deep hollow is felt at the back part of the joint, which is much increased on flexing the limb. The patient at the same time loses, more or less, the power of extending the forearm.

In fracture of the *radius* below the insertion of the Biceps brachii, but above the insertion of the Pronator teres, the upper fragment is strongly supinated by the Biceps brachii and Supinator, and at the same time drawn forwards by the Biceps brachii, the lower fragment is pronated and drawn towards the ulna by both Pronators. Thus there is extreme displacement with very little deformity. This fracture should be treated with the hand in full supination so as to insure that lower fragment of the radius will be supinated to the extent of the upper fragment.

FIG. 596.—A fracture of the body of the radius.

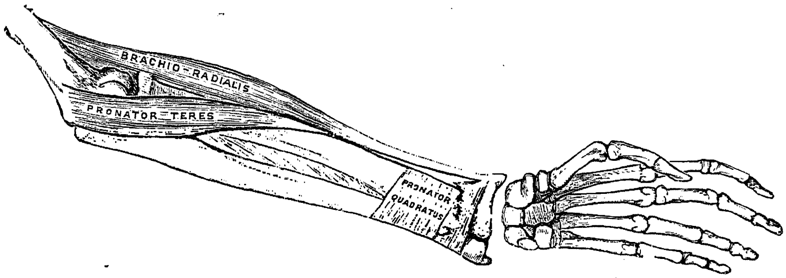


In fractures of the radius below the insertion of the Pronator teres (fig. 596), the upper fragment is drawn upwards by the Biceps brachii and medialwards by the Pronator teres, into a position midway between pronation and supination, and a degree of fulness in the upper half of the forearm is thus produced. The lower fragment is drawn downwards towards the ulna and pronated by the Pronator quadratus; at the same time, the Brachioradialis, by elevating the styloid process, into which it is inserted, will serve to depress the upper end of the lower fragment still more towards the ulna.

In fracture of the *body of the ulna* the upper fragment retains its usual position, but the lower is drawn towards the radius by the Pronator quadratus, producing a well-marked depression at the seat of fracture, and some fulness on the dorsal and volar surfaces of the forearm.

In fracture of the *bodies of the radius and ulna together,* the lower fragments are drawn upwards, sometimes forwards, sometimes backwards, according to the direction of the fracture, by the combined actions of the flexor and extensor muscles, producing a degree of fulness on either the dorsal or volar surface of the forearm. At the same time the lower fragments are drawn into contact by the Pronator quadratus, the radius being in a state of pronation. The upper fragment of the radius is drawn upwards and medialwards by the Biceps brachii and Pronator teres to a higher level than the ulna; the upper portion of the ulna is slightly elevated by the Brachialis.

Fig. 597.—A fracture of the lower end of the radius.



In fracture of the *lower end of the radius* (fig. 597) the displacement produced is very considerable, and bears some resemblance to dislocation of the carpus backwards, from which it should be carefully distinguished. The lower fragment is displaced backwards and upwards, but this displacement is due to the force of the blow driving the portion of the bone into this position, and not to any muscular influence. The upper fragment projects forwards, often lacerating the substance of the Pronator quadratus, and is drawn by this muscle into close contact with the lower end of the ulna, causing a projection on the volar surface of the forearm, immediately above the carpus, from the flexor tendons being thrust forwards. This fracture may be distinguished from dislocation by the relative positions of the styloid processes of the radius and ulna (the former of which is displaced upwards in fracture) and by the deformity being removed on making sufficient extension, when crepitus may be occasionally detected. The age of the patient will assist in determining whether the injury is fracture or separation of the epiphysis. During treatment of this fracture the wrist should be kept fully hyperextended (p. 395).

THE FASCIÆ AND MUSCLES OF THE LOWER EXTREMITY

The muscles of the lower extremity are subdivided into groups corresponding with the different regions of the limb.

I. Muscles of the iliac region.
II. Muscles of the thigh.
III. Muscles of the leg.
IV. Muscles of the foot.

I. The Muscles of the Iliac Region (fig. 598)

Psoas major. Psoas minor. Iliacus.

The **fascia iliaca** covers the Psoas and Iliacus. It is thin above, and becomes gradually thicker as it approaches the inguinal ligament.

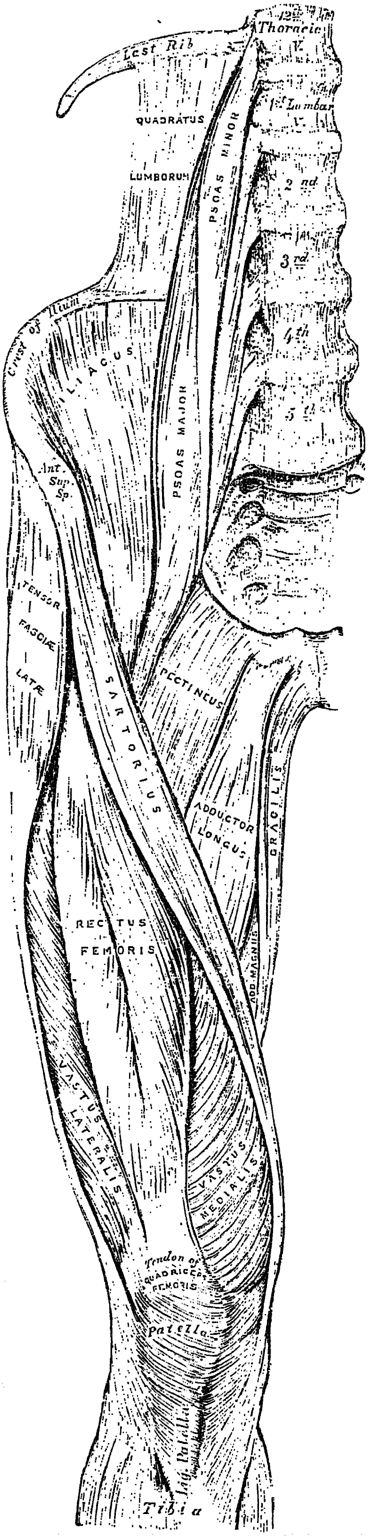
The *portion covering the Psoas* is thickened above to form the medial lumbocostal arch which stretches from the transverse process of the first to the body of the second lumbar vertebra. Medially, this portion of the fascia is attached by a series of arched processes to the intervertebral fibrocartilages, and prominent margins of the bodies of the vertebræ, and to the upper part of the sacrum. Laterally, above the crest of the ilium, it is continuous with the fascia covering the front of the Quadratus lumborum (p. 481), while below the crest of the ilium it is continuous with the fascia covering the Iliacus.

The *portion covering the Iliacus* is connected, laterally, to the whole length of the inner lip of the iliac crest; and medially, to the brim of the lesser pelvis, where it blends with the periosteum. It is attached to the iliopectineal eminence, and there receives a slip from the tendon of insertion of the Psoas minor when that muscle exists. The external iliac vessels lie in front of the fascia but the branches of the lumbar plexus are behind it; it is separated from the peritoneum by a part of the subperitoneal connective tissue (fascia of Abernethy).

Lateral to the femoral vessels, the iliac fascia is intimately connected to the posterior margin of the inguinal ligament, and is continuous with the transversalis fascia. It passes behind the femoral vessels, and beyond the inguinal ligament becomes the *iliopectineal fascia*. This fascia divides the space between the inguinal ligament and the hip-bone into a medial and a lateral lacuna; the medial (lacuna vasorum) transmits the femoral vessels, the lateral (lacuna musculorum) the Psoas major, the Iliacus and the femoral nerve. Medial to the vessels the iliopectineal fascia is attached to the pecten pubis, and is continuous with the pectineal fascia. In the thigh the iliopectineal fascia covers the Iliacus and the Psoas major, and forms the posterior wall of the femoral sheath.

The **Psoas major** (fig. 598) is a long fusiform muscle placed on the side of the lumbar region of the vertebral column and the brim of the lesser pelvis. It arises (1) from the anterior surfaces and lower borders of the transverse processes of all the lumbar vertebræ; (2) by five slips or digitations, each of which takes origin from the bodies of two vertebræ and their intervertebral fibrocartilage; the highest slip arises from the lower margin of the body of the twelfth thoracic vertebra, the upper margin of the body of the first lumbar vertebra and the interposed fibrocartilage, the lowest slip from the adjacent margins of the bodies of the fourth and fifth lumbar vertebræ and the interposed fibrocartilage; (3) from a series of tendinous arches extending across the constricted parts of the bodies of the lumbar vertebræ between the preceding slips; the lumbar arteries and veins, and filaments from the sympathetic trunk, pass beneath these arches. The muscle proceeds downwards across the brim of the lesser pelvis, passes behind the inguinal ligament and in front of the capsule of the hip-joint, and ends in a tendon. The latter receives nearly the whole of the fibres of the Iliacus and is

Fig. 598.—The muscles of the iliac region and the anterior femoral muscles. Right side.



inserted into the lesser trochanter of the femur. A large bursa, which may communicate with the cavity of the hip-joint, separates the tendon from the os pubis and the capsule of the joint.

Relations.—In the abdomen the Psoas major is in relation by its *anterior surface* with the medial lumbocostal arch, the fascia covering the muscle, the extraperitoneal connective tissue and peritoneum, the kidney, Psoas minor, renal vessels, ureter, testicular (or ovarian) vessels, and genito-femoral nerve. In front of the right Psoas is the inferior vena cava and the terminal portion of the ileum, and in front of the left the colon. Its *posterior surface* is in relation with the transverse processes of the lumbar vertebræ, and the Quadratus lumborum. The lumbar plexus is situated in the posterior part of the substance of the muscle. *Medially*, the muscle is in relation with the bodies of the lumbar vertebræ, the lumbar arteries, the gangliated trunk of the sympathetic, the lumbar lymph-glands, and along the brim of the pelvis with the external iliac artery ; medial to the right muscle is the inferior vena cava, and to the left muscle the aorta.

In the thigh it is in relation, *in front*, with the fascia lata ; *behind*, with the capsule of the hip-joint from which it is separated by a bursa ; by its *medial border*, with the Pectineus and medial femoral circumflex artery, and also with the femoral artery, which slightly overlaps it ; by its *lateral border*, with the Iliacus.

The femoral nerve descends at first through the fibres of Psoas major, then lies between it and the Iliacus, and at the level of the inguinal ligament is in front of the muscle.

Nerve-supply.—The Psoas major is supplied by branches from the second and third lumbar nerves.

Actions.—The Psoas major acts conjointly with the Iliacus.

The **Psoas minor** (fig. 598) is placed in front of the Psoas major within the abdomen. It arises from the sides of the bodies of the twelfth thoracic and first lumbar vertebræ and from the fibrocartilage between them. It ends in a long flat tendon which is inserted into the pecten pubis and iliopectineal eminence, and, by its lateral border, into the iliac fascia. This muscle is absent in about 40 per cent. of subjects.

Nerve-supply.—The Psoas minor is supplied by a branch from the first lumbar nerve.

Action.—The Psoas minor is a tensor of the iliac fascia.

The **Iliacus** (fig. 598) is a flat, triangular muscle, which fills the iliac fossa. It arises from the upper two-thirds of the iliac fossa, from the inner lip of the iliac crest, from the anterior sacro-iliac and iliolumbar ligaments, and from the ala of the sacrum ; in front, it reaches as far as the anterior superior and anterior inferior iliac spines, and receives a few fibres from the upper part of the articular capsule of the hip-joint. Most of its fibres converge to be inserted into the lateral side of the tendon of the Psoas major, but some of them are attached to the body of the femur for 2·5 cm. below and in front of the lesser trochanter.*

Relations.—Within the abdomen the Iliacus is in relation by its *anterior surface* with the iliac fascia, which separates the muscle from the extraperitoneal connective tissue and peritoneum, and with the lateral femoral cutaneous nerve ; on the right side, with the cæcum ; on the left side, with the iliac part of the descending colon ; by its *posterior surface*, with the iliac fossa ; by its *medial border*, with the Psoas major and femoral nerve.

In the thigh, it is in relation, by its *anterior surface*, with the fascia lata, Rectus femoris, Sartorius, and arteria profunda femoris ; by its *posterior surface*, with the capsule of the hip-joint, a bursa common to it and the Psoas major being interposed.

Nerve-supply.—The Iliacus is supplied by branches of the second and third lumbar nerves, through the femoral nerve.

Actions.—The Psoas major, acting from above, flexes the thigh upon the pelvis, being assisted by the Iliacus ; acting from below, with the femur fixed, it bends the lumbar portion of the vertebral column forwards and to its own side, and then, in conjunction with the Iliacus, tilts the pelvis forwards. When the Psoas major and Iliacus of both sides act from below, they serve to maintain the erect posture by supporting the vertebral column and pelvis upon the femora, or in continued action bend the trunk and pelvis forwards, as in raising the trunk from the recumbent posture.

Applied Anatomy.—There is no definite septum between the portions of fascia covering the Psoas and Iliacus respectively, and the fascia is only connected to the subjacent muscles by a quantity of loose connective tissue. When an abscess forms beneath this

* The Psoas major and Iliacus are sometimes regarded as a single muscle named the *Iliopsoas.*

fascia, as it is very apt to do, the pus is contained in an osseofibrous cavity which is closed on all sides within the abdomen, and is open only at its lower part, where the fascia is prolonged over the muscles into the thigh. When the disease is in the thoracic vertebræ, the matter tracks down the posterior mediastinal cavity in front of the bodies of the vertebræ, and, passing beneath the medial lumbocostal arch, enters the sheath of the Psoas, down which it travels as far as the pelvic brim; it then gets beneath the iliac portion of the fascia, and fills up the iliac fossa. In consequence of the attachment of the fascia to the linea terminalis, it rarely finds its way into the lesser pelvis, but passes by a narrow opening under the inguinal ligament into the thigh, lateral to the femoral vessels. It thus follows that a psoas abscess may be described as consisting of four parts, (1) a somewhat narrow channel at its upper part, in the psoas sheath; (2) a dilated sac in the iliac fossa; (3) a constricted neck under the inguinal ligament; and (4) a dilated sac in the upper part of the thigh. When the lumbar vertebræ are the seat of the disease, the matter finds its way directly into the substance of the Psoas. The muscular fibres are destroyed, and the nerves contained in the abscess are isolated and exposed in its interior; the iliac vessels which lie in front of the fascia remain intact, and the peritoneum seldom becomes implicated. All psoas abscesses do not, however, pursue this course; the pus may leave the sheath of the muscle above the crest of the ilium, and tracking backwards may point in the loin (*lumbar abscess*); or it may point above the inguinal ligament in the inguinal region; or it may follow the course of the branches of the hypogastric vessels into the lesser pelvis, and, passing through the greater sciatic foramen, discharge itself on the back of the thigh.

II. The Muscles of the Thigh

1. The Anterior Femoral Muscles (fig. 598)

Tensor fasciæ latæ.
Sartorius.

Quadriceps femoris $\begin{cases}\text{Rectus femoris.}\\ \text{Vastus lateralis.}\\ \text{Vastus medialis.}\\ \text{Vastus intermedius.}\end{cases}$

Articularis genus.

The **superficial fascia** forms a continuous layer over the whole of the thigh; it consists of areolar tissue containing in its meshes much fat, and may be separated into two or more layers, between which are found the superficial vessels and nerves. It varies in thickness in different parts of the limb; in the groin it is thick, and the two layers are separated from one another by the superficial inguinal lymph-glands, the great saphenous vein, and several smaller vessels. The superficial layer is continuous above with the superficial fascia of the abdomen. The deep layer of the superficial fascia is a very thin, fibrous stratum, best marked on the medial side of the great saphenous vein and below the inguinal ligament. It is placed beneath the subcutaneous vessels and nerves and upon the surface of the fascia lata. It is intimately adherent to the fascia lata a little below the inguinal ligament. It covers the fossa ovalis (saphenous opening), being closely united to its circumference, and is connected to the sheath of the femoral vessels. The portion covering the fossa ovalis is perforated by the great saphenous vein, small blood-vessels, and lymph-vessels, hence it has been termed the *fascia cribrosa*, the openings for these vessels having been likened to the holes in a sieve. A large subcutaneous bursa is found in the superficial fascia over the patella.

The **deep fascia** of the thigh is named, from its great extent, the *fascia lata*; it constitutes an investment for the whole of this region of the limb, but varies in thickness in different parts. Thus, it is thicker in the upper and lateral parts of the thigh, where it receives a fibrous expansion from the Glutæus maximus, and where the Tensor fasciæ latæ is inserted between its layers; it is very thin behind, and at the upper and medial parts, where it covers the Adductor muscles, but becomes stronger around the knee, where it receives fibrous expansions from the tendon of the Biceps femoris laterally, from the Sartorius medially, and from the Quadriceps femoris in front. The fascia lata is attached, above and behind, to the back of the sacrum and coccyx; laterally, to the iliac crest; in front, to the inguinal ligament and to the superior ramus of the os pubis; and medially, to the inferior ramus of the os pubis, to the inferior ramus and tuberosity of the ischium, and to the lower border of the sacrotuberous ligament. From its attachment to the iliac crest it descends as a dense fascia over the Glutæus medius to the upper border of the Glutæus

maximus, where it splits into two layers, one passing superficial and the other deep to this muscle; at the lower border of the muscle the two layers reunite. The portion of the fascia lata attached to the front part of the iliac crest, and corresponding to the origin of the Tensor fasciæ latæ, extends down the lateral side of the thigh as two layers, one superficial and the other deep to this muscle; at the lower end of the muscle these two layers unite, and form a strong band, having first received the insertion of the muscle. This band is continued downwards, under the name of the *iliotibial tract* (iliotibial band), and is attached to the lateral condyle of the tibia. The layer of the iliotibial tract which lies deep to the Tensor fasciæ latæ is prolonged upwards to join the lateral part of the capsule of the hip-joint. The greater part of the tendon of the Glutæus maximus is inserted into the iliotibial tract. Below, the fascia lata is attached to all the prominent points around the knee-joint, viz. the condyles of the femur and tibia, and the head of the fibula. On either side of the patella it is strengthened by transverse fibres from the lower parts of the Vasti, which are attached to and support this bone. Of these the lateral are the stronger, and are continuous with the iliotibial tract. The fascia lata gives off two strong intermuscular septa which are attached to the whole length of the linea aspera of the femur and its prolongations above and below: the lateral and stronger septum, which extends from the insertion of the Glutæus maximus to the lateral condyle, separates the Vastus lateralis in front from the short head of the Biceps femoris behind, and gives partial origin to these muscles; the medial and thinner septum separates the Vastus medialis from the Adductores and the Pectineus. Besides these there are numerous smaller septa, separating the individual muscles, and enclosing each in a distinct sheath.

The **fossa ovalis** (saphenous opening) (fig. 599).—At the upper and medial part of the thigh, a little below the medial end of the inguinal ligament, is a large oval aperture in the fascia lata; it transmits the great saphenous vein, and other smaller vessels, and is termed the *fossa ovalis*. The fascia cribrosa, which is pierced by the structures passing through the opening, closes the aperture and must be removed to expose it. The fascia lata in this part of the thigh is described as consisting of a superficial and a deep portion.

The *superficial portion* of the fascia lata is the part on the lateral side of the fossa ovalis. It is attached to the crest and anterior superior spine of the ilium, to the whole length of the inguinal ligament, and to the pecten pubis in conjunction with the lacunar ligament. From the tubercle of the os pubis it is reflected downwards and lateralwards, as an arched margin, the *falciform margin*, forming the lateral boundary of the fossa ovalis; this margin overlies and is adherent to the anterior layer of the sheath of the femoral vessels, and the fascia cribrosa is attached to it. The upward and medial prolongation of the falciform margin is named the *superior cornu*; its downward and medial prolongation, the *inferior cornu*. The latter is well defined, and is continuous behind the great saphenous vein with the pectineal fascia.

The *deep portion* is situated on the medial side of the fossa ovalis, and is continuous with the superficial portion at the lower margin of the fossa; traced upwards, it covers the Pectineus, Adductor longus, and Gracilis, and, passing behind the sheath of the femoral vessels, to which it is closely united, is continuous with the iliopectineal fascia, and is attached to the pecten pubis.

From this description it may be observed that the superficial portion of the fascia lata lies in front of the femoral vessels, and the deep portion behind them, so that an apparent aperture exists between the two, through which the great saphenous vein passes to join the femoral vein.

The **Tensor fasciæ latæ** (fig. 598) arises from the anterior 5 cm. of the outer lip of the iliac crest; from the outer surface of the anterior superior iliac spine, and part of the outer border of the notch below it, between the Glutæus medius and Sartorius; and from the deep surface of the fascia lata. It is inserted between the two layers of the iliotibial tract of the fascia lata about the junction of the middle with the upper one-third of the thigh.

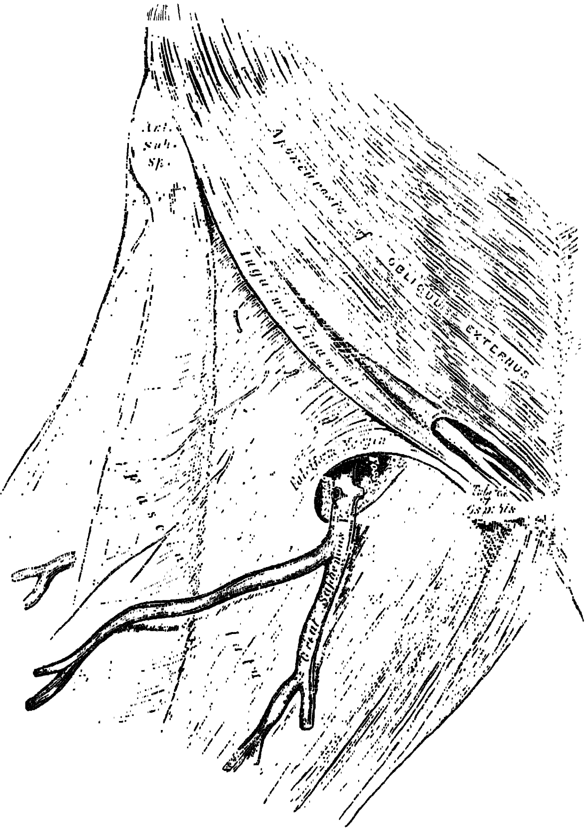
Nerve-supply.—The Tensor fasciæ latæ is supplied by the fourth and fifth lumbar and first sacral nerves through the superior glutæal nerve.

Actions.—The Tensor fasciæ latæ tightens the fascia lata; continuing its action it abducts the thigh and rotates it inwards. In the erect posture, acting from

below, it serves to steady the pelvis on the head of the femur; through the iliotibial tract it steadies the condyles of the femur on the tibia.

The **Sartorius** (figs. 598, 600, 602), the longest muscle in the body, is narrow and ribbon-like; it arises by tendinous fibres from the anterior superior iliac spine and the upper one-half of the notch below it. It crosses obliquely the upper and anterior parts of the thigh, from the lateral to the medial side, then descends vertically, as far as the medial side of the knee, passing behind the medial condyle of the femur to end in a tendon. This curves obliquely forwards and expands into a broad aponeurosis, which is inserted, in front of the Gracilis and Semitendinosus, into the upper part of the medial surface of the body of the tibia, nearly as far forwards as the anterior crest. The

FIG. 599.—The right fossa ovalis (saphenous opening).



upper part of the aponeurosis is curved backwards over the upper edge of the tendon of the Gracilis so as to be inserted behind it. An offset, from its upper margin, blends with the capsule of the knee-joint, and another, from its lower border, with the fascia on the medial side of the leg.

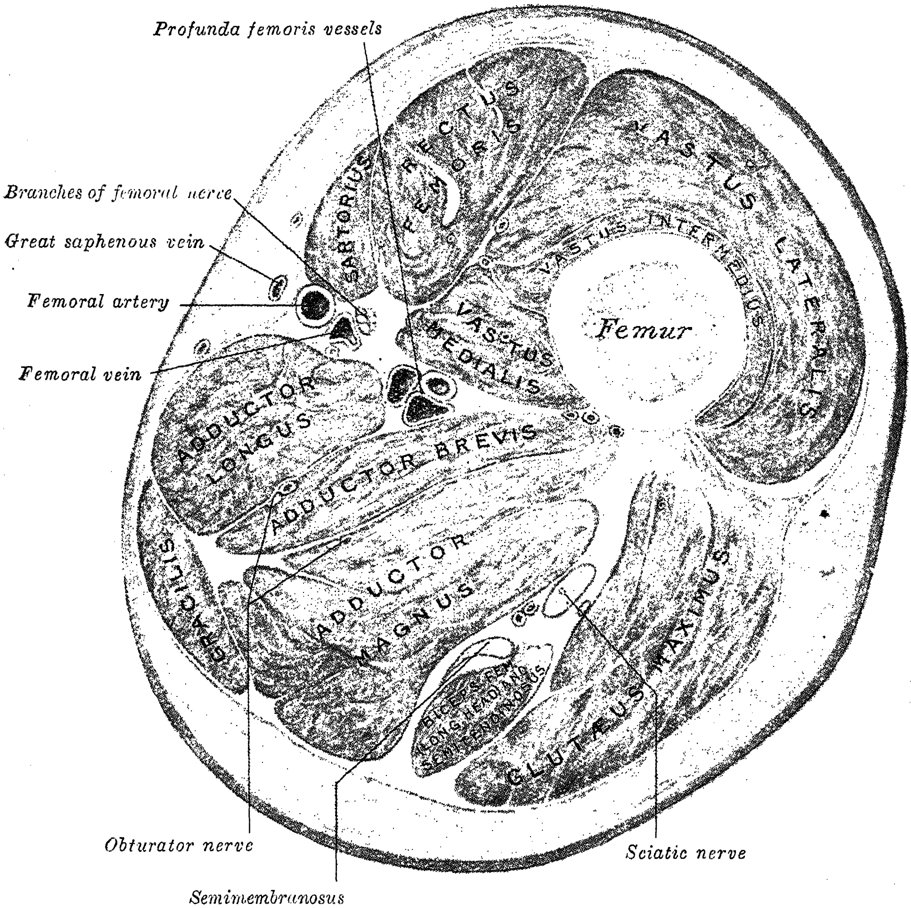
The relations of this muscle to the femoral artery are important, as it constitutes the chief guide in tying the vessel. In the upper one-third of the thigh it forms the lateral side of a triangle, the *femoral* (*Scarpa's*) *triangle*, the medial side of which is formed by the medial border of the Adductor longus, and the base by the inguinal ligament; the femoral artery passes through the middle of this triangle from its base to its apex. In the middle one-third of the thigh, the femoral artery is contained in the *adductor* (*Hunter's*) *canal*, on the roof of which the Sartorius lies (fig. 602).

Nerve-supply.—The Sartorius is supplied by the second and third lumbar nerves through the femoral nerve.

Actions.—The Sartorius flexes the leg on the thigh, and the thigh on the pelvis; it also abducts the thigh and rotates it outwards. Acting from below it flexes the pelvis on the thigh and rotates it towards the opposite side.

The **Quadriceps femoris** (figs. 598, 600, 602) is the great extensor muscle of the leg, and consists of a large fleshy mass which covers the front and sides of the femur. It is subdivided into separate portions, which have received distinctive names. One occupies the middle of the thigh, and arises from the ilium; from its straight course it is called the *Rectus femoris*. The other three take origin from the body of the femur, which they cover from the trochanters to the condyles; that on the lateral side of the femur is termed the *Vastus lateralis*; that on the medial side, the *Vastus medialis*; and that in front, the *Vastus intermedius*.

Fig. 600.—A transverse section through the thigh at the level of the apex of the femoral triangle. Four-fifths of natural size.



The **Rectus femoris** is fusiform in shape, and its superficial fibres are arranged in a bipennate manner, the deep fibres running straight down to the deep aponeurosis. It arises by two tendons: an anterior or straight, from the anterior inferior iliac spine, and a posterior or reflected, from a groove above the brim of the acetabulum. The two unite at an acute angle, and spread into an aponeurosis which is prolonged downwards on the anterior surface of the muscle, and from this the muscular fibres arise. The muscle ends in a broad and thick aponeurosis which occupies the lower two-thirds of its posterior surface, and, gradually becoming narrowed into a flattened tendon, is inserted into the base of the patella.

The **Vastus lateralis** is the largest part of the Quadriceps femoris. It arises by a broad aponeurosis, which is attached to the upper part of the intertrochanteric line, to the anterior and inferior borders of the greater trochanter, to the lateral lip of the glutæal tuberosity, and to the upper one-half

The **Obliquus externus abdominis** (fig. 550), situated on the lateral and anterior parts of the abdomen, is the largest and the most superficial of the three flat muscles in this region. It arises, by eight fleshy slips, from the external surfaces and inferior borders of the lower eight ribs; these slips interdigitate with the slips of origin of the Serratus anterior and Latissimus dorsi, and are arranged in an oblique line which runs downwards and backwards, the upper ones being attached close to the cartilages of the corresponding ribs, the lowest to the apex of the cartilage of the last rib, the intermediate ones to

FIG. 552.—A superficial dissection of the groin and the lower part of the anterior abdominal wall. Left side.

the ribs at some distance from their cartilages. From these attachments the fleshy fibres proceed in various directions. Those from the lowest ribs pass nearly vertically downwards, and are inserted into the anterior half of the outer lip of the iliac crest; the middle and upper fibres, directed downwards and forwards, end in an aponeurosis, opposite a line drawn from the prominence of the ninth costal cartilage to the anterior superior iliac spine. The posterior border of the muscle is free.

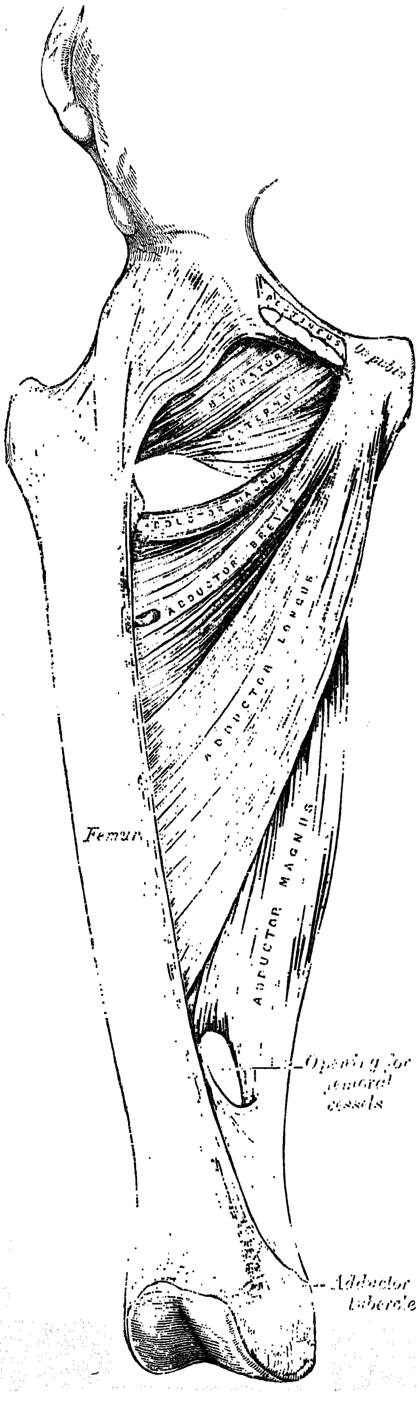
The *aponeurosis* of the Obliquus externus abdominis is a thin but strong membranous structure, the fibres of which are directed downwards and medialwards. It is joined with that of the opposite muscle along the middle line, and the aponeuroses of the two muscles cover the front of the abdomen; above, it is covered by, and gives origin to, the lower fibres of the Pectoralis major; below, its fibres are closely aggregated together, and extend obliquely across from the anterior superior iliac spine to the pubic tubercle and the pectineal line. In the middle line, its fibres end in the *linea alba* (fig. 550), a tendinous band which extends from the xiphoid process to the symphysis pubis.

2. The Medial Femoral Muscles.

Gracilis.	Adductor longus.	Adductor magnus.
Pectineus.	Adductor brevis.	

The **Gracilis** (figs. 598, 600, 602) is the most superficial muscle on the medial side of the thigh. It is thin and flattened, broad above, narrow and tapering below. It arises by a thin aponeurosis from the anterior margins of the lower one-half of the symphysis pubis and the upper one-half of the pubic arch. The fibres run vertically downwards, and end in a rounded tendon, which passes behind the medial condyle of the femur, curves round the medial condyle of the tibia, where it becomes flattened, and is inserted into the upper part of the medial surface of the body of the tibia, below the condyle. A few fibres from the lower part of the tendon are prolonged into the deep fascia of the leg. At its insertion the tendon is situated immediately above that of the Semitendinosus, and its upper edge is overlapped by the tendon of the Sartorius, with which it is in part blended. It is separated from the tibial collateral ligament of the knee-joint by a bursa common to it and the tendon of the Semitendinosus.

Fig. 601.—The deep medial femoral muscles. Right side.



Nerve-supply.—The Gracilis is supplied by the second and third lumbar nerves through the obturator nerve.

Actions.—The Gracilis flexes the leg and rotates it inwards; it also adducts the thigh.

The **Pectineus** (fig. 598) is a flat, quadrangular muscle, situated at the anterior part of the upper and medial aspect of the thigh. It arises from the pecten pubis, and to a slight extent from the surface of bone in front of it, between the iliopectineal eminence and pubic tubercle, and from the fascia covering the anterior surface of the muscle; the fibres pass downwards, backwards, and lateralwards, to be inserted into the femur, along a line leading from the lesser trochanter to the linea aspera.*

Relations.—Its *anterior surface* is in relation with the fascia lata, which separates it from the femoral vessels and great saphenous vein; its *posterior surface*, with the capsule of the hip-joint, the Adductor brevis, Obturator externus, and the anterior branch of

* The Pectineus may consist of two incompletely separated strata: the lateral or dorsal stratum, which is constant, is supplied by a branch from the femoral nerve, or in the absence of this branch by the accessory obturator nerve; the medial or ventral stratum, when present, is supplied by the obturator nerve.—A. M. Paterson, *Journal of Anatomy and Physiology*, vol. xxvi. p. 43.

the obturator nerve ; its *lateral border*, with the Psoas major and the medial femoral circumflex vessels ; its *medial border*, with the margin of the Adductor longus.

Nerve-supply.—The Pectineus is supplied by the second and third lumbar nerves, through the femoral nerve ; and by the third lumbar through the accessory obturator when this nerve is present. Occasionally it receives a branch from the obturator nerve.

Actions.—The Pectineus adducts the thigh and flexes it on the pelvis.

The **Adductor longus** (figs. 601, 602), the most superficial of the three adductors, is a triangular muscle, lying in the same plane as the Pectineus. It arises by a flat, narrow tendon, from the front of the os pubis in the angle between the crest and the symphysis. It soon expands into a broad fleshy belly which passes downwards, backwards, and lateralwards, and is inserted, by an aponeurosis, into the middle one-third of the linea aspera of the femur, between the Vastus medialis and the Adductor magnus, with both of which it is usually blended.

Relations.—Its *anterior surface* is in relation with the fascia lata, the Sartorius, and, near its insertion, with the femoral artery and vein ; its *posterior surface*, with the Adductores brevis et magnus, the anterior branch of the obturator nerve, and near its insertion with the profunda femoris vessels ; its *lateral border*, with the Pectineus ; its *medial border*, with the Gracilis.

Nerve-supply.—The Adductor longus is supplied by the second and third lumbar nerves through the obturator nerve.

Actions.—The Adductor longus adducts the thigh, flexes it on the pelvis, and rotates it outwards.

Applied Anatomy.—The Adductor longus is liable to be severely strained in those who ride much on horseback, or its tendon may be ruptured by suddenly gripping the saddle. Occasionally, especially in cavalry soldiers, the tendon becomes ossified, constituting the 'rider's bone.'

The **Adductor brevis** (figs. 600, 601) is situated behind the Pectineus and Adductor longus. It is somewhat triangular in form, and arises by a narrow origin from the outer surface of the inferior ramus of the os pubis, between the Gracilis and Obturator externus. Its fibres, passing backwards, lateralwards, and downwards, are inserted by an aponeurosis into the femur, along the line leading from the lesser trochanter to the linea aspera and into the upper part of the linea aspera, immediately behind the Pectineus and the upper part of the Adductor longus.

Relations.—Its *anterior surface* is in relation with the Pectineus, Adductor longus, arteria profunda femoris, and anterior branch of the obturator nerve ; its *posterior surface*, with the Adductor magnus, and posterior branch of the obturator nerve; its *lateral border*, with the medial femoral circumflex artery, the Obturator externus, and conjoined tendon of the Psoas major and Iliacus ; its *medial border*, with the Gracilis and Adductor magnus. It is pierced near its insertion by the second, or first and second, perforating branches of the arteria profunda femoris.

Nerve-supply.—The Adductor brevis is supplied by the third and fourth lumbar nerves, through the obturator nerve.

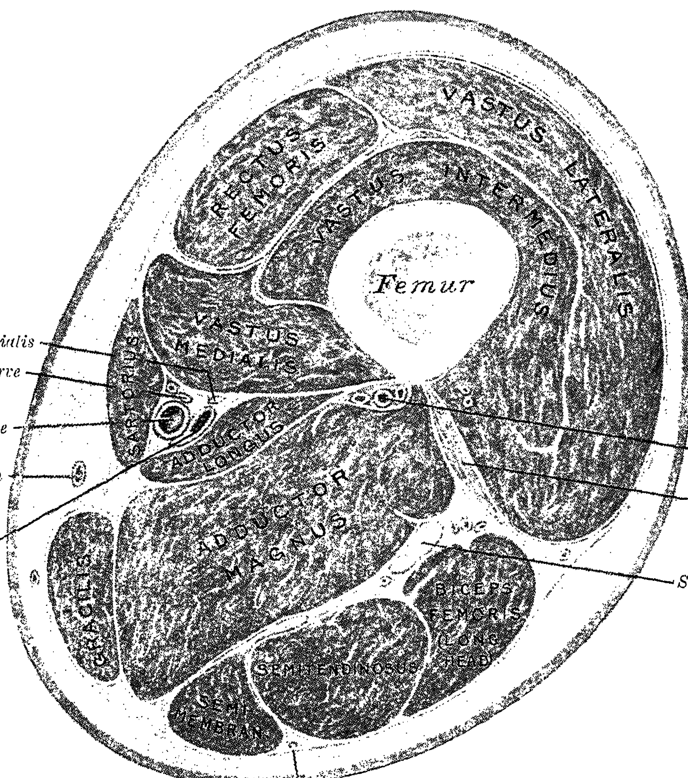
Actions.—The Adductor brevis adducts the thigh, flexes it on the pelvis and rotates it outwards.

The **Adductor magnus** (figs. 600, 601, 602) is a large triangular muscle, situated on the medial side of the thigh. It arises from a small part of the inferior ramus of the os pubis, from the inferior ramus of the ischium, and from the lateral margin of the inferior part of the tuberosity of the ischium. Those fibres which arise from the ramus of the os pubis are short, horizontal in direction, and are inserted into the rough line leading from the greater trochanter of the femur to the linea aspera, medial to the Glutæus maximus* ; those from the ramus of the ischium are directed downwards and lateralwards with different degrees of obliquity, to be inserted, by means of a broad aponeurosis, into the

* These uppermost fibres are sometimes described as a separate muscle—the *Adductor minimus*—which is situated somewhat in front of the other parts of the muscle.

linea aspera and the upper part of its medial prolongation below. The medial portion of the muscle, composed principally of the fibres arising from the tuberosity of the ischium, forms a thick fleshy mass which descends almost vertically, and ends about the lower one-third of the thigh in a rounded tendon which is inserted into the adductor tubercle on the medial condyle of the femur, and is connected by a fibrous expansion to the line leading upwards from the tubercle to the linea aspera. At the insertion of the muscle, there is a series of osseo-aponeurotic openings, formed by tendinous arches attached

FIG. 602.—A transverse section through the middle of the thigh. Four-fifths of natural size.



to the bone. The upper four openings are small, and give passage to the perforating branches of the arteria profunda femoris. The lowest is of large size, and transmits the femoral vessels to the popliteal fossa.

Relations.—Its *anterior surface* is in relation with the Pectineus, Adductores brevis et longus, the femoral and profunda vessels, and the posterior branch of the obturator nerve; a bursa intervenes between the highest part of the muscle and the lesser trochanter of the femur; its *posterior surface*, with the sciatic nerve, the Glutæus maximus, Biceps femoris, Semitendinosus, and Semimembranosus. Its *superior border* lies parallel with the Quadratus femoris, the superficial branch of the medial femoral circumflex artery passing between them; its *medial border* is in relation with the Gracilis, Sartorius, and fascia lata.

Nerve-supply.—The Adductor magnus is supplied by the third and fourth lumbar nerves through the obturator nerve, and by a branch from the sacral plexus through the sciatic nerve.

Actions.—The Adductor magnus adducts the thigh and rotates it outwards; it also flexes the thigh on the pelvis. The Pectineus and the Adductores adduct the thigh powerfully; they are especially used in horse exercise, the sides of the

saddle being grasped between the knees by the contraction of these muscles; they rotate the thigh outwards, and when the limb has been abducted, they draw it medialwards, carrying the thigh across that of the opposite side. In progression, they assist in drawing forwards the lower limb. If the lower extremities be fixed, these muscles, taking their fixed points below, act upon the pelvis, serving to maintain the body in an erect posture; or, if their action be continued, flex the pelvis forwards upon the femur.

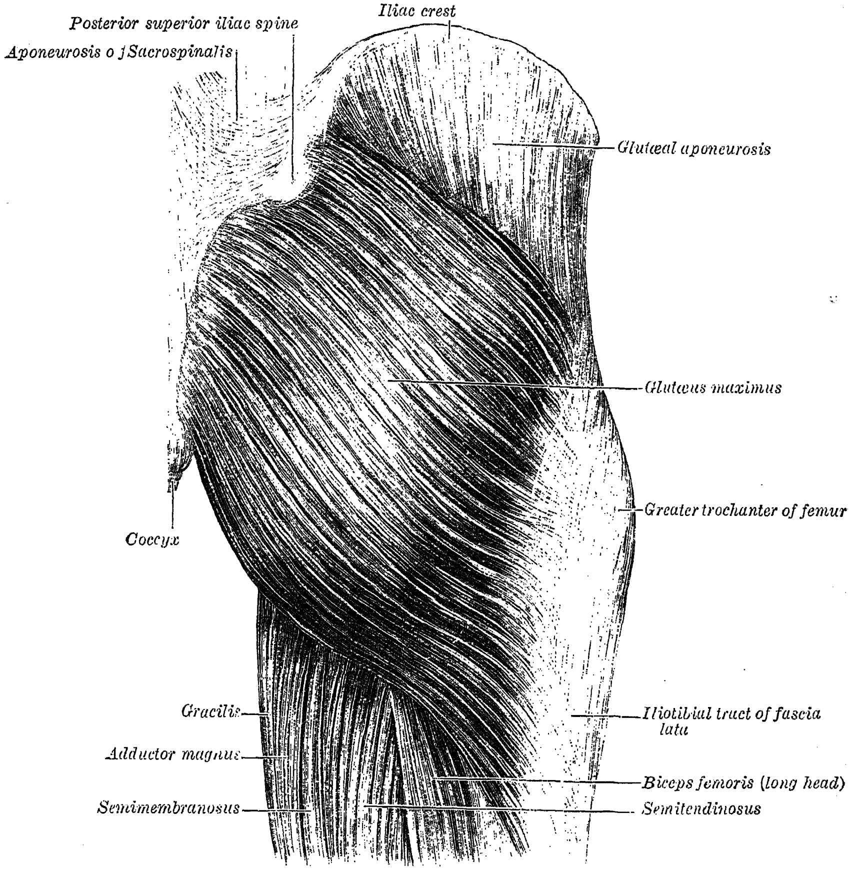
3. The Muscles of the Glutæal Region

Glutæus maximus.	Obturator internus.
Glutæus medius.	Gemellus superior.
Glutæus minimus.	Gemellus inferior.
Piriformis.	Quadratus femoris.

Obturator externus.

The **Glutæus maximus** (fig. 603), the largest and most superficial muscle in the glutæal region, is a broad and thick fleshy mass of a quadrilateral shape, and

Fig. 603.—The right glutæus maximus muscle.



forms the prominence of the buttock. Its large size is one of the most characteristic features of the muscular system in man, connected as it is with the power he has of maintaining the trunk in the erect posture. The muscle is remarkably coarse in structure, being made up of fasciculi lying parallel with one another, and collected into large bundles separated by fibrous septa. It

arises from the posterior glutæal line of the ilium, and the rough portion of bone, including the crest, immediately above and behind it; from the aponeurosis of the Sacrospinalis; from the posterior surface of the lower part of the sacrum and the side of the coccyx; from the sacrotuberous ligament, and from the fascia (glutæal aponeurosis) covering the Glutæus medius. The fibres run obliquely downwards and lateralwards; those forming the upper and larger portion of the muscle, together with the superficial fibres of the lower portion, end in a thick tendinous lamina, which passes across the greater trochanter, and is inserted into the iliotibial tract of the fascia lata; the deeper fibres of the lower portion of the muscle are inserted into the glutæal tuberosity of the femur between the Vastus lateralis and Adductor magnus.

Three *bursæ* are usually found in relation with the deep surface of this muscle. One, of large size, and generally multilocular, separates it from the greater trochanter; a second, often wanting, is situated on the tuberosity of the ischium; a third is found between the tendon of the muscle and that of the Vastus lateralis.

Relations.—Its *superficial surface* is in relation with a thin fascia which separates it from the subcutaneous tissue; its *deep surface*, with the ilium, sacrum, coccyx, and sacrotuberous ligament, part of the Glutæus medius, Piriformis, Gemelli, Obturator internus, Quadratus femoris, the tuberosity of the ischium, greater trochanter, the origins of the Biceps femoris, Semitendinosus, Semimembranosus, and the Adductor magnus. The superficial part of the superior glutæal artery reaches the deep surface of the muscle by passing between the Piriformis and the Glutæus medius; the inferior glutæal and internal pudendal vessels and the sciatic, pudendal, and lateral femoral cutaneous nerves, and muscular branches from the sacral plexus, issue from the pelvis below the Piriformis. The first perforating artery and the terminal branches of the medial circumflex femoral artery are also found under cover of the lower part of the muscle. Its *upper border* is thin, and is connected with the Glutæus medius by the glutæal aponeurosis. Its *lower border* is free and prominent, and is crossed by the fold of the nates.

Nerve-supply.—The Glutæus maximus is supplied by the fifth lumbar and the first and second sacral nerves through the inferior glutæal nerve.

Actions.—When the Glutæus maximus takes its fixed point from the pelvis, it extends the thigh and brings it into line with the trunk. Taking its fixed point below, it supports the pelvis and the trunk upon the head of the femur. Its most powerful action is to raise the trunk after stooping by drawing the pelvis backwards. It is a tensor of the fascia lata, and through the iliotibial tract it steadies the femur on the tibia during standing, when the extensor muscles are relaxed.

The **Glutæus medius** is a broad, thick, radiating muscle, situated on the outer surface of the pelvis. Its posterior one-third is covered by the Glutæus maximus, its anterior two-thirds by the glutæal aponeurosis, which separates it from the superficial fascia and integument. It arises from the outer surface of the ilium between the iliac crest and posterior glutæal line above, and the anterior glutæal line below; it also arises from the strong fascia which covers the upper part of its outer surface. The fibres converge to a flattened tendon, which is inserted into the oblique ridge directed downwards and forwards on the lateral surface of the greater trochanter of the femur. A bursa separates the tendon from the surface of the trochanter over which it glides.

Nerve-supply.—The Glutæus medius is supplied by the fourth and fifth lumbar and first sacral nerves, through the superior glutæal nerve.

Actions.—The Glutæus medius abducts the thigh; its anterior fibres rotate the thigh inwards.

The **Glutæus minimus** (fig. 604), the smallest of the Glutæi, is placed immediately beneath the preceding. It is fan-shaped, arising from the outer surface of the ilium, between the anterior and inferior glutæal lines, and behind, from the margin of the greater sciatic notch. The fibres converge to the deep surface of an aponeurosis, and this ends in a tendon which is inserted into a ridge on the lateral part of the anterior surface of the greater trochanter of the femur, and gives an expansion to the capsule of the hip-joint. A bursa is interposed between the tendon and the medial part of the anterior surface of the greater trochanter.

Between the Glutæus medius and Glutæus minimus are the deep branches of the superior glutæal vessels, and the superior glutæal nerve. Deep to the Glutæus minimus are the reflected tendon of the Rectus femoris and the capsule of the hip-joint.

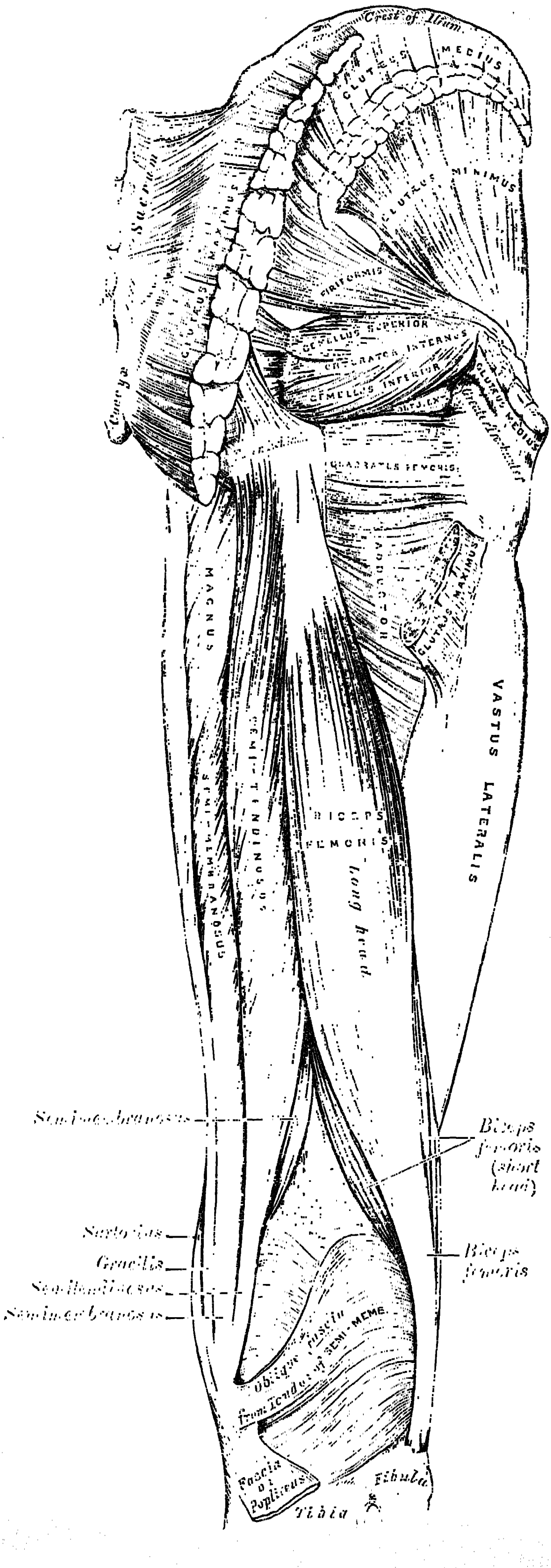
Nerve-supply.—The Glutæus minimus is supplied by the fourth and fifth lumbar and first sacral nerves, through the superior glutæal nerve.

Actions. — The Glutæus minimus is an abductor of the thigh; its anterior fibres rotate the thigh inwards.

The **Piriformis** (fig. 604) lies almost parallel with the posterior margin of the Glutæus medius. It is situated partly within the pelvis against its posterior wall, and partly at the back of the hip-joint. It arises from the front of the sacrum by three fleshy digitations, attached to the portions of bone between the anterior sacral foramina, and to the grooves leading from the foramina: a few fibres also arise from the margin of the greater sciatic foramen, and from the anterior surface of the sacrotuberous ligament. The muscle passes out of the pelvis through the greater sciatic foramen, and is inserted by a rounded tendon into the upper border of the greater trochanter of the femur, behind and above, but often partly blended with, the common tendon of the Obturator internus and Gemelli.

Relations.—*Within the pelvis* the *anterior surface* of the Piriformis is in relation with the rectum (especially on the left side), the sacral plexus of nerves, and branches of the hypogastric vessels; its *posterior surface* with the sacrum. *Outside the pelvis*, its *anterior surface* is in contact with the posterior surface of the ischium and capsule of the hip-joint; and its *posterior surface*, with the Glutæus maximus. Its *upper border* is in relation with the Glutæus medius, and the superior glutæal vessels and nerve; its *lower border*, with the Gemellus superior and Coccygeus. The inferior glutæal and internal pudendal vessels, and the sciatic, posterior femoral cutaneous, and pudendal nerves, and muscular branches from the sacral plexus, appear on the buttock between the Piriformis and Gemellus superior. The muscle is frequently pierced by the common peronæal nerve.

Fig. 604.—The muscles of the glutæal region and the posterior femoral muscles. Right side.

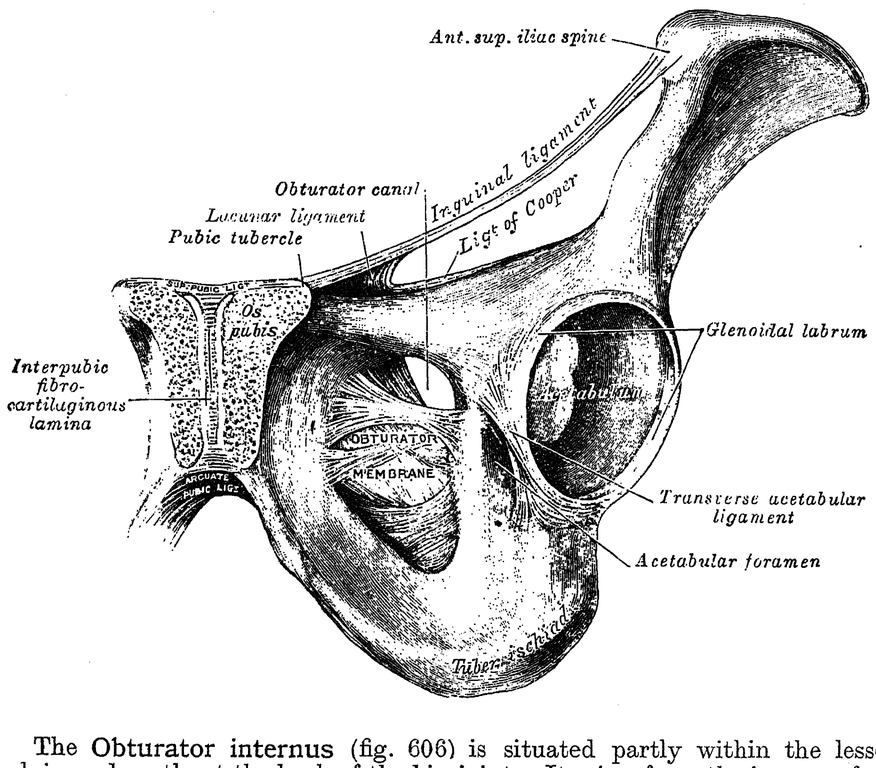


Nerve-supply.—The Piriformis is supplied by twigs from the first and second sacral nerves.

Action.—The Piriformis rotates the thigh outwards.

The **obturator membrane** (fig. 605) is a thin fibrous sheet, which almost completely closes the obturator foramen. Its fibres are arranged in interlacing bundles mainly transverse in direction; the uppermost bundle is attached to the obturator tubercles and completes the obturator canal for the passage of the obturator vessels and nerve. The membrane is attached to the sharp margin of the obturator foramen except at its lower lateral angle, where it is fixed to the pelvic surface of the inferior ramus of the ischium, i.e. within the margin. Both Obturator muscles are connected with this membrane.

FIG. 605.—The left obturator membrane. External aspect.

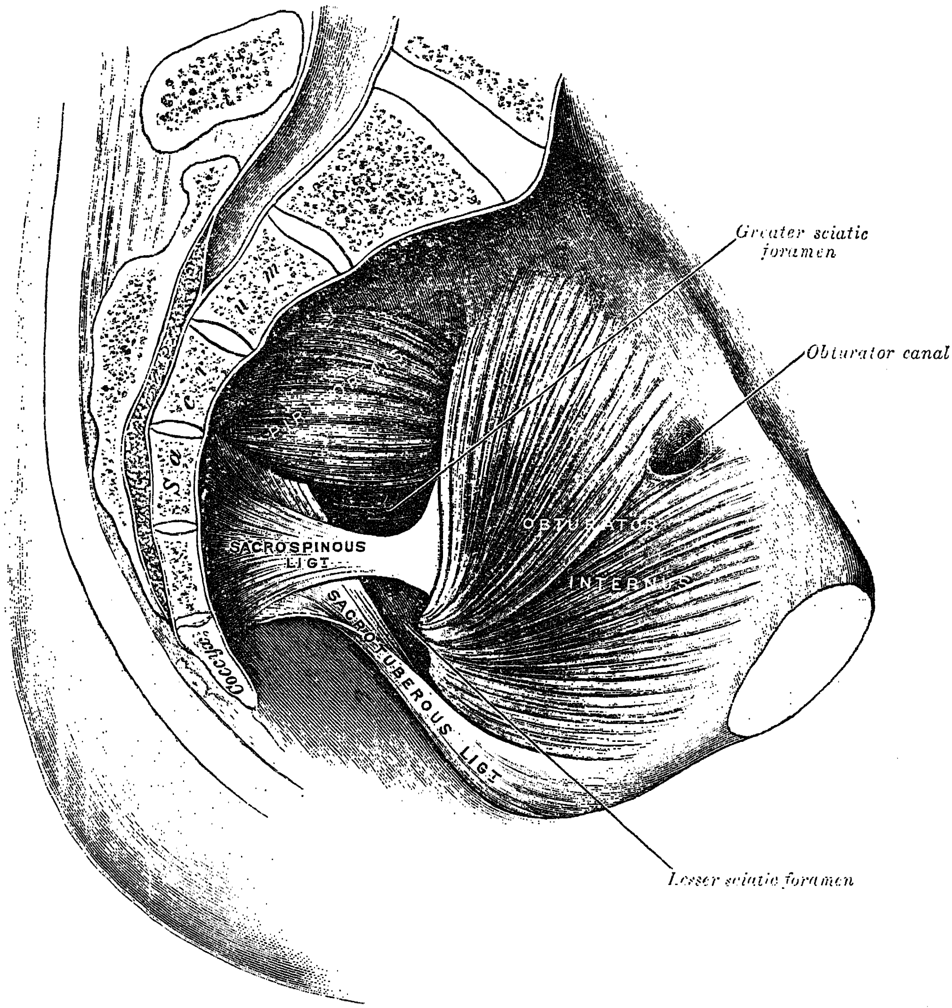


The **Obturator internus** (fig. 606) is situated partly within the lesser pelvis, and partly at the back of the hip-joint. It arises from the inner surface of the anterolateral wall of the pelvis, where it surrounds the greater part of the obturator foramen, being attached to the inferior rami of the os pubis and ischium and to the inner surface of the hip-bone below and behind the pelvic brim, reaching from the upper part of the greater sciatic foramen above and behind to the obturator foramen below and in front. It also arises from the medial part of the pelvic surface of the obturator membrane, from the tendinous arch which completes the canal for the passage of the obturator vessels and nerve, and to a slight extent from the obturator fascia, which covers the muscle. The fibres converge rapidly towards the lesser sciatic foramen and end in four or five tendinous bands on the deep surface of the muscle; these bands are reflected at a right angle over the grooved surface of the ischium between its spine and tuberosity. The grooved surface is covered by smooth cartilage, which is separated from the tendon by a bursa, and presents one or more ridges corresponding with the furrows between the tendinous bands. These bands leave the pelvis through the lesser sciatic foramen and unite into a single flattened tendon, which passes horizontally across the capsule of the hip-joint, and, after receiving the attachments of the Gemelli, is inserted into the fore part of the medial surface of the greater trochanter of the femur,

above and in front of the trochanteric fossa. A bursa, narrow and elongated in form, is usually found between the tendon and the capsule of the hip-joint; it occasionally communicates with the bursa between the tendon and the ischium.

Relations.—*Within the pelvis*, the *anterolateral surface* of the muscle is in relation with the obturator membrane and inner surface of the anterior wall of the pelvis; its *pelvic surface*, with the obturator fascia, and the origin of the Levator ani, and with the

FIG. 606.—The left Obturator internus. Pelvic aspect.



internal pudendal vessels and pudendal nerve, which cross it. The pelvic surface forms the lateral boundary of the ischiorectal fossa. *Outside the pelvis*, the muscle is covered by the Glutæus maximus, crossed by the sciatic nerve, and rests on the back of the hip-joint. As the tendon of the Obturator internus emerges from the lesser sciatic foramen it is overlapped both in front and behind by the two Gemelli which form a muscular canal for it; near its insertion the Gemelli pass in front of the tendon and form a groove in which it lies.

Nerve-supply.—The Obturator internus is supplied by a branch which receives its fibres from the fifth lumbar and first and second sacral nerves.

Action.—The Obturator internus rotates the thigh outwards.

The **Gemelli** (fig. 604) are two small muscular fasciculi, accessories to the tendon of the Obturator internus which is received into a groove between them.

The **Gemellus superior**, the smaller of the two, arises from the outer surface of the spine of the ischium, blends with the upper part of the tendon of the Obturator internus, and is inserted with it into the medial surface of the greater trochanter of the femur. It is sometimes wanting.

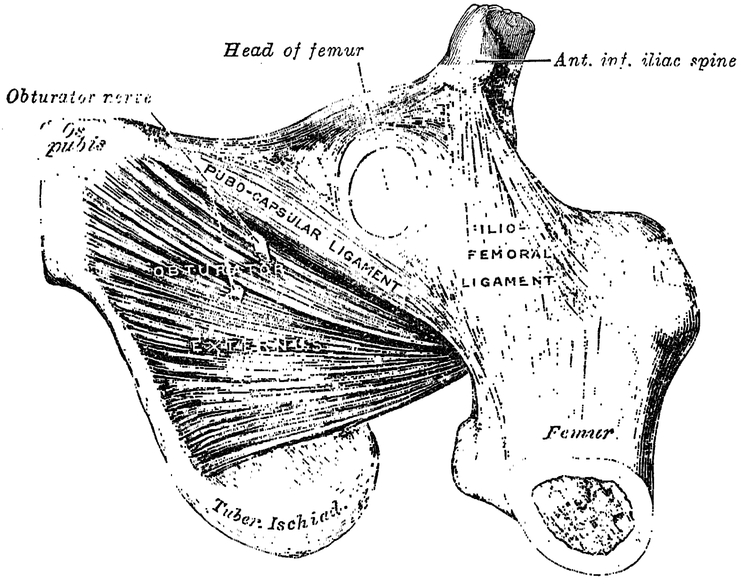
Nerve-supply.—The Gemellus superior is supplied by the fifth lumbar and first and second sacral nerves, through the nerve to the Obturator internus.

The **Gemellus inferior** arises from the upper part of the tuberosity of the ischium, immediately below the groove for the Obturator internus tendon. It blends with the lower part of the tendon of the Obturator internus, and is inserted with it into the medial surface of the greater trochanter.

Nerve-supply.—The Gemellus inferior is supplied by the fourth and fifth lumbar and first sacral nerves through the nerve to the Quadratus femoris.

Actions.—The Gemelli superior et inferior rotate the thigh outwards.

FIG. 607.—The left Obturator externus.



The **Quadratus femoris** (fig. 604) is a flat, quadrilateral muscle, between the Gemellus inferior and the upper margin of the Adductor magnus; it is separated from the latter by the superficial branch of the medial femoral circumflex artery. It arises from the upper part of the external border of the tuberosity of the ischium, and is inserted into the upper part of the linea quadrata of the femur. A bursa is often found between the front of this muscle and the lesser trochanter.

Nerve-supply.—The Quadratus femoris is supplied by a branch which receives its fibres from the fourth and fifth lumbar and first sacral nerves.

Action.—The Quadratus femoris is an external rotator of the thigh.

The **Obturator externus** (fig. 607) is a flat, triangular muscle, which covers the outer surface of the anterior wall of the pelvis. It arises from the margin of bone immediately around the medial side of the obturator foramen, viz. from the rami of the os pubis, and the inferior ramus of the ischium; it also arises from the medial two-thirds of the outer surface of the obturator membrane, and from the tendinous arch which completes the canal for the passage of the obturator vessels and nerves. The fibres springing from the inferior ramus of the ischium extend on to the inner surface of the bone, where they obtain a narrow origin between the margin of the foramen and the attachment of the obturator membrane. The fibres converge and pass backwards, lateralwards, and upwards, and end in a tendon which runs across the back of the neck of the femur and lower part of the capsule of the hip-joint and is inserted into the trochanteric fossa of the femur. The obturator vessels lie between

the muscle and the obturator membrane; the anterior branch of the obturator nerve reaches the thigh by passing in front of the muscle, and the posterior branch by piercing it.

Nerve-supply.—The Obturator externus is supplied by the third and fourth lumbar nerves through the obturator nerve.

Action.—The Obturator externus is an external rotator of the thigh.

4. The Posterior Femoral Muscles (fig. 604)

Biceps femoris. Semitendinosus. Semimembranosus.

The **Biceps femoris** (figs. 600, 602, 604) is situated on the posterolateral aspect of the thigh. It has two heads of origin: one, the long head, arises from the lower and medial impression on the posterior part of the ischial tuberosity, by a tendon common to it and the Semitendinosus, and from the lower part of the sacrotuberous ligament; the other, the short head, from the lateral lip of the linea aspera of the femur, between the Adductor magnus and Vastus lateralis, extending up almost as high as the insertion of the Glutæus maximus; from the lateral prolongation of the linea aspera to within 5 cm. of the lateral condyle; and from the lateral intermuscular septum. The fibres of the long head form a fusiform belly, which passes downwards and lateralwards across the sciatic nerve to end in an aponeurosis; this aponeurosis covers the posterior surface of the muscle, receives on its deep surface the fibres of the short head, and gradually contracts into a tendon, which is inserted into the lateral side of the head of the fibula, and by a small slip into the lateral condyle of the tibia. This tendon forms the lateral hamstring and divides into two portions which embrace the fibular collateral ligament of the knee-joint; from its posterior border a thin expansion is given off to the fascia of the leg. The common peronæal nerve descends along its medial border.

Nerve-supply.—The Biceps femoris is supplied by the fifth lumbar, and first, second and third sacral nerves; the long head through the tibial nerve, the short head through the common peronæal nerve.

Actions.—The Biceps femoris, acting from above, flexes the leg on the thigh, and when the knee is semiflexed rotates the leg slightly outwards. Acting from below it serves to support the pelvis on the head of the femur and draws the trunk backwards as in raising it from the stooping position.

The **Semitendinosus** (figs. 602, 604), remarkable for the great length of its tendon of insertion, is situated at the posterior and medial aspect of the thigh. It arises from the lower and medial impression on the tuberosity of the ischium, by a tendon common to it and the long head of the Biceps femoris; it also arises from an aponeurosis connecting the adjacent surfaces of the two muscles to the extent of about 7·5 cm. from their origin. The muscle is fusiform and ends a little below the middle of the thigh in a long round tendon which lies along the medial side of the popliteal fossa; the tendon curves around the medial condyle of the tibia, passes over the tibial collateral ligament of the knee-joint, from which it is separated by a bursa, and is inserted into the upper part of the medial surface of the body of the tibia behind the insertion of the Sartorius and below that of the Gracilis. At its insertion it is united with the tendon of the Gracilis and gives off a prolongation to the deep fascia of the leg. A tendinous intersection is usually observed about the middle of the muscle.

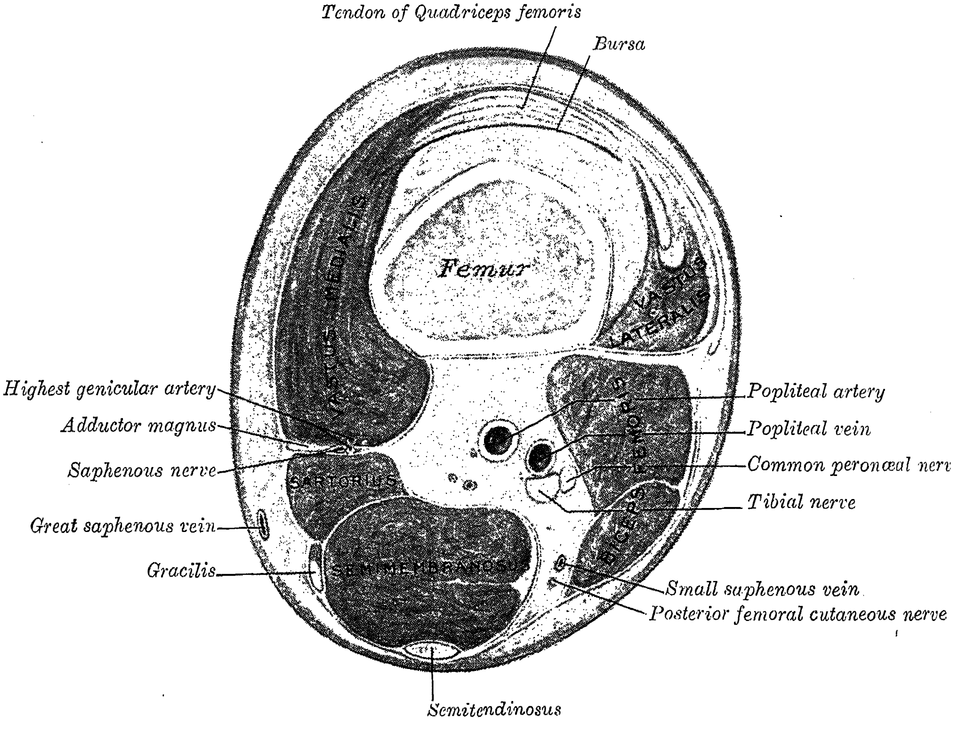
Nerve-supply.—The Semitendinosus is supplied by the fifth lumbar, and first, second and third sacral nerves, through the tibial nerve.

Actions.—Acting from above it flexes the knee-joint, and when the joint is semiflexed rotates the leg slightly inwards. When its fixed point is below its action is similar to that of the Biceps femoris.

The **Semimembranosus** (figs. 602, 604, 608), so called from its membranous tendon of origin, is situated at the back and medial side of the thigh. It arises by a thick tendon from the upper and lateral impression on the tuberosity of the ischium, above and lateral to the Biceps femoris and Semitendinosus, and is inserted into the groove on the back of the medial condyle of the tibia.

The tendon of origin expands into an aponeurosis, which passes downwards under cover of the Semitendinosus and long head of the Biceps femoris; from this aponeurosis muscular fibres arise, and converge to another aponeurosis which covers the lower part of the posterior surface of the muscle and contracts into the tendon of insertion. The tendon of insertion gives off certain fibrous expansions: one, of considerable size, passes upwards and lateralwards to be inserted into the back part of the lateral condyle of the femur, forming part of the oblique popliteal ligament of the knee-joint; a second is continued downwards to the fascia which covers the Popliteus muscle; while a few fibres

FIG. 608.—A transverse section through the thigh, 4 cm. proximal to the adductor tubercle of the femur. Four-fifths of natural size.



join the tibial collateral ligament of the knee-joint and the fascia of the leg. The muscle overlaps the upper part of the popliteal vessels.

The tendons of insertion of the Semitendinosus and Semimembranosus form the medial hamstrings.

Nerve-supply.—The Semimembranosus is supplied by the fifth lumbar and first, second and third sacral nerves through the tibial nerve.

Actions.—The actions of the Semimembranosus are similar to those of the Semitendinosus.

Applied Anatomy.—In disease of the knee-joint, contraction of the hamstring tendons is a frequent complication; this causes flexion of the leg, and a partial dislocation of the tibia backwards, with a slight degree of rotation outwards, probably due to the action of the Biceps femoris. The hamstring tendons occasionally require subcutaneous division in some forms of spurious ankylosis of the knee-joint dependent upon permanent contraction and rigidity of the muscles, or from contracture of the ligamentous and other tissues surrounding the joint, the result of disease. The relation of the common peronæal nerve, which lies in close apposition to the medial border of the tendon of the Biceps femoris, must always be borne in mind in dividing this tendon, and a free incision with exposure of the tendon, before division, is the safer proceeding.

In the operation of stretching the sciatic nerve to cure sciatica the tendon of origin of the Semimembranosus may be mistaken for the nerve.

III. The Muscles of the Leg

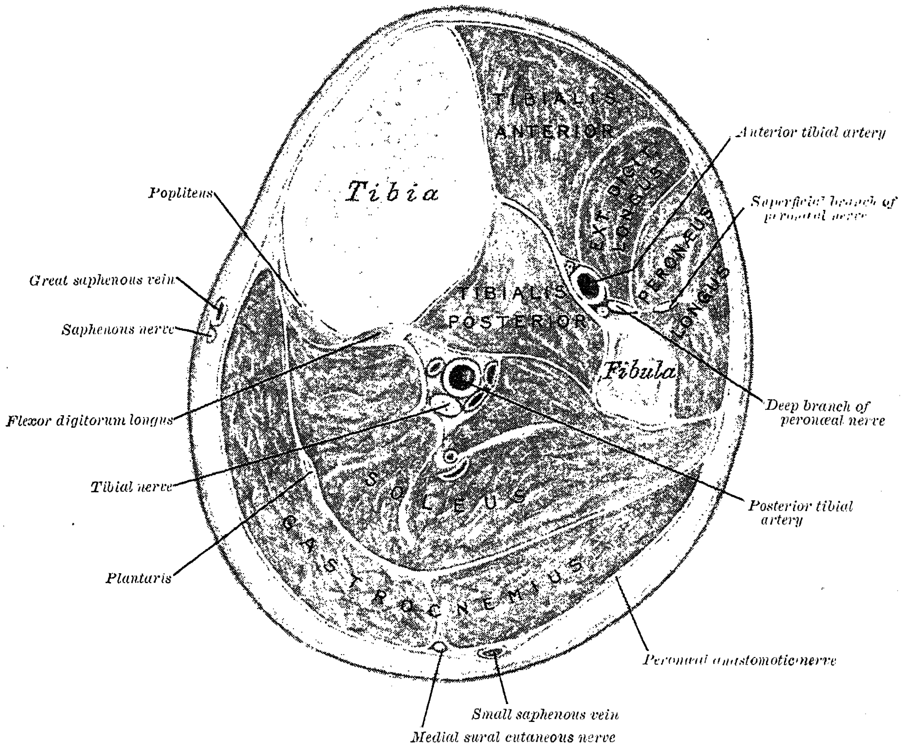
The muscles of the leg may be divided into three groups: anterior, posterior, and lateral.

1. The Anterior Crural Muscles (fig. 610)

Tibialis anterior. Extensor hallucis longus. Extensor digitorum longus. Peronæus tertius.

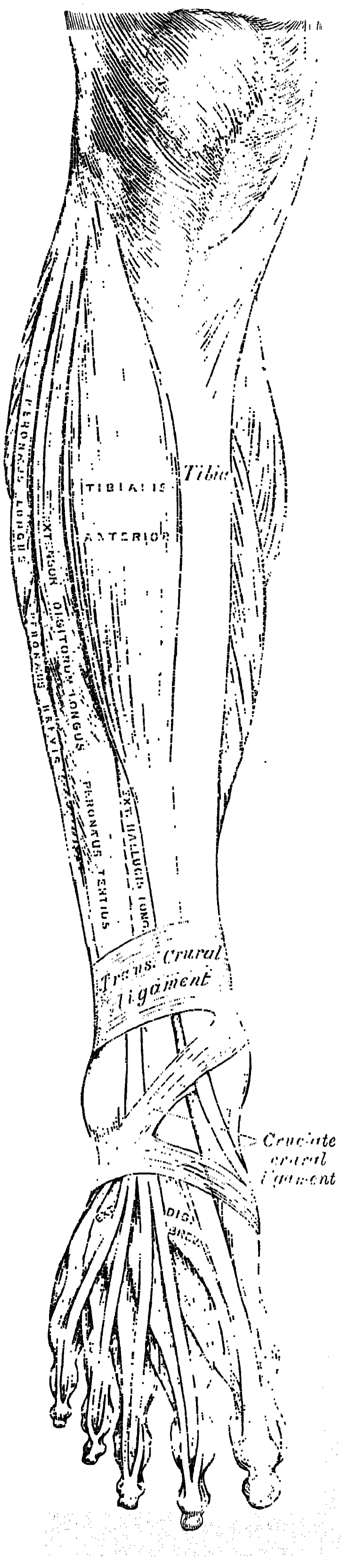
The **fascia cruris** or deep fascia of the leg is continuous above with the fascia lata, and is attached around the knee to the patella, the ligamentum patellæ, the tuberosity and condyles of the tibia, and the head of the fibula.

Fig. 609.—A transverse section through the leg, 9 cm. distal to the knee-joint.



Behind, it forms the popliteal fascia which covers the popliteal fossa; here it is strengthened by transverse fibres, and perforated by the small saphenous vein. It receives an expansion from the tendon of the Biceps femoris laterally, and expansions from the tendons of the Sartorius, Gracilis, Semitendinosus, and Semimembranosus medially; it blends with the periosteum covering the subcutaneous surface of the tibia, and with that covering the head and malleolus of the fibula; below, it is continuous with the transverse crural and laciniate ligaments. It is thick and dense in the upper and anterior part of the leg, and gives origin, by its deep surface, to some fibres of the Tibialis anterior and Extensor digitorum longus; it is thinner behind, where it covers the Gastrocnemius and Soleus. On the lateral side of the leg it gives off the *anterior* and *posterior fibular intermuscular septa* which are attached respectively to the anterolateral and posterolateral borders of the fibula; in the anterior and posterior crural regions the fascia also gives off several slender processes which enclose the individual muscles. A broad transverse intermuscular septum, called the *deep transverse fascia of the leg*, intervenes between the superficial and deep posterior crural muscles.

FIG. 610.—The right anterior crural muscles.



The **Tibialis anterior** (figs. 609, 610) is situated on the lateral side of the tibia; it is thick and fleshy above, tendinous below. It arises from the lateral condyle and upper one-half or two-thirds of the lateral surface of the body of the tibia; from the adjoining part of the anterior surface of the interosseous membrane; from the deep surface of the fascia cruris; and from the intermuscular septum between it and the Extensor digitorum longus. The fibres run vertically downwards, and end in a tendon which is apparent on the anterior surface of the muscle at the lower one-third of the leg; after passing through the medial compartments of the transverse and cruciate crural ligaments, it is inserted into the medial and under surfaces of the first cuneiform bone, and the base of the first metatarsal bone. This muscle overlaps the anterior tibial vessels and deep peronæal nerve in the upper part of the leg.

Nerve-supply.—The Tibialis anterior is supplied by the fourth and fifth lumbar and first sacral nerves, through the deep peronæal nerve.

Actions.—The Tibialis anterior is a flexor of the ankle-joint; it also raises the medial border of the foot, i.e. inverts the foot.

The **Extensor hallucis longus** (figs. 610, 615) is a thin muscle, situated between the Tibialis anterior and the Extensor digitorum longus. It arises from the anterior surface of the fibula for about the middle two-fourths of its extent, medial to the origin of the Extensor digitorum longus; it also arises from the anterior surface of the interosseous membrane to a similar extent. The anterior tibial vessels and deep peronæal nerve lie between it and the Tibialis anterior. The fibres pass downwards, and end in a tendon, which occupies the anterior border of the muscle, passes through a compartment in the cruciate crural ligament, crosses to the medial side of the anterior tibial vessels near the ankle-joint, and is inserted into the base of the distal phalanx of the great toe. Opposite the metatarsophalangeal articulation a thin prolongation is given off from either side of the tendon and covers the dorsal surface of the joint. An expansion from the medial side of the tendon is usually inserted into the base of the proximal phalanx.

Nerve-supply.—The Extensor hallucis longus is supplied by the fourth and fifth lumbar and first sacral nerves through the deep peronæal nerve.

Actions. — The Extensor hallucis longus extends the phalanges of the great toe; in continued action it flexes the ankle-joint.

The **Extensor digitorum longus** (figs. 609, 610, 615) is a pennate muscle, situated at the lateral part of the front of the leg. It arises from the lateral condyle of the tibia, the upper three-fourths of the anterior surface

of the body of the fibula, the upper part of the anterior surface of the interosseous membrane, the deep surface of the fascia cruris, the anterior fibular intermuscular septum and the septum between it and the Tibialis anterior. Between it and the Tibialis anterior are the upper portions of the anterior tibial vessels and the deep peronæal nerve. The tendon passes under the transverse and cruciate crural ligaments in company with the Peronæus tertius, and divides into four slips, which run forward on the dorsum of the foot, and are inserted into the second and third phalanges of the four lesser toes. The tendons to the second, third, and fourth toes are each joined, opposite the metatarsophalangeal articulation, on the lateral side by a tendon of the Extensor digitorum brevis. The tendons are inserted as follows: each receives a fibrous expansion from the corresponding Lumbricalis and Interossei, and then spreads out into a broad aponeurosis, which covers the dorsal surface of the first phalanx; at the articulation of the first with the second phalanx this aponeurosis divides into three slips—an intermediate, which is inserted into the base of the second phalanx; and two collateral slips, which, after uniting with one another on the dorsal surface of the second phalanx, are inserted into the base of the third phalanx.

Nerve-supply.—The Extensor digitorum longus is supplied by the fourth and fifth lumbar and first sacral nerves, through the deep peronæal nerve.

Actions.—The Extensor digitorum longus extends the phalanges of the toes, and when its action is continued flexes the ankle-joint.

The **Peronæus tertius** (figs. 610, 615) is a part of the Extensor digitorum longus, and might be described as its fifth tendon. The fibres belonging to this tendon arise from the lower one-third or more of the anterior surface of the fibula, the lower part of the anterior surface of the interosseous membrane, and the anterior fibular intermuscular septum. The tendon passes under the transverse and cruciate crural ligaments in the same compartment as the Extensor digitorum longus, and is inserted into the dorsal surface of the base of the fifth metatarsal bone, but often spreads into a thin sheet which extends forwards along the shaft of the bone. This muscle is sometimes wanting.

Nerve-supply.—The Peronæus tertius is supplied by the fourth and fifth lumbar and first sacral nerves, through the deep peronæal nerve.

Actions.—The Peronæus tertius flexes the ankle-joint; it also raises the lateral border of the foot, i.e. everts the foot.

2. The Posterior Crural Muscles

The muscles of the back of the leg are subdivided into two groups—superficial and deep. Those of the superficial group constitute a powerful muscular mass, forming the calf of the leg. Their large size is one of the most characteristic features of the muscular apparatus in man, and bears a direct relation to his erect attitude and his mode of progression.

Superficial Group (fig. 611).

Gastrocnemius. Soleus. Plantaris.

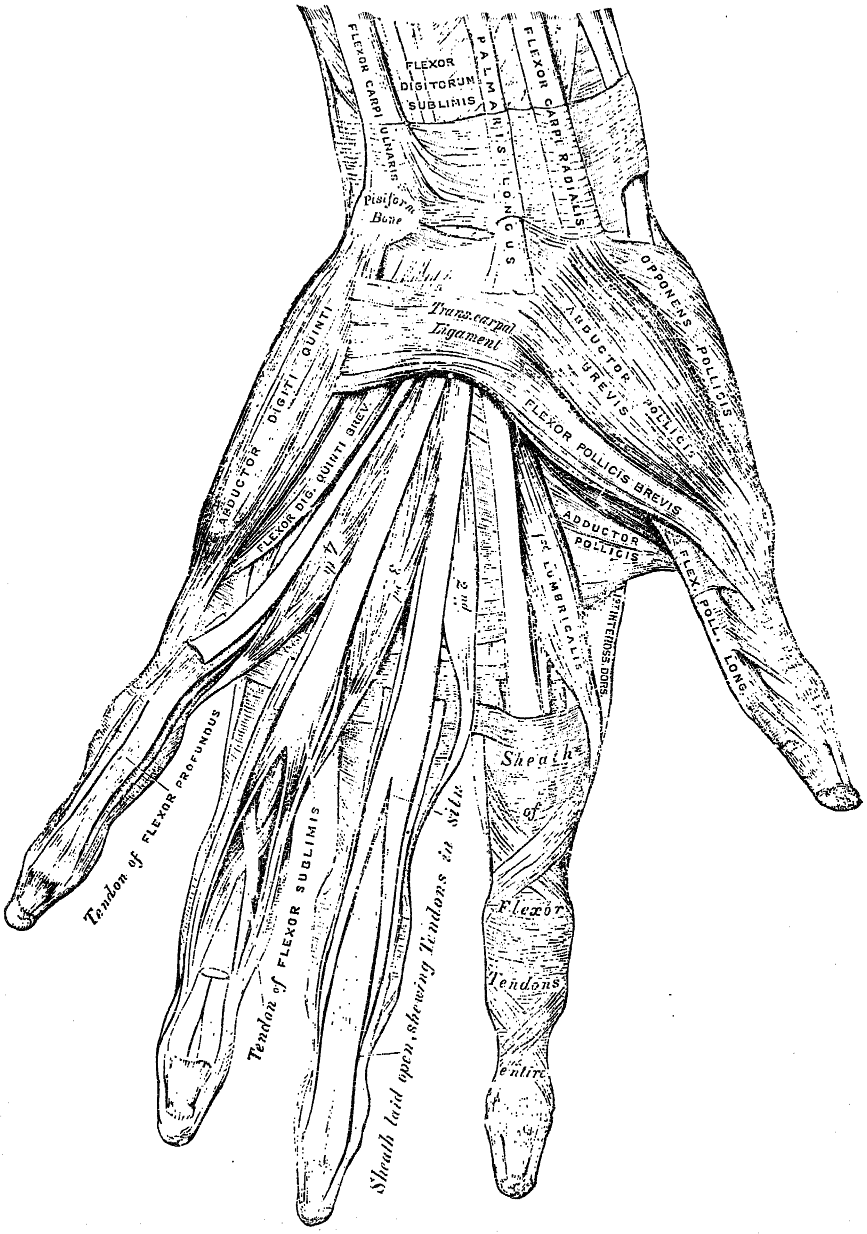
The **Gastrocnemius** (figs. 609, 611) is the most superficial of the group, and forms the greater part of the calf. It arises by two heads, which are connected to the condyles of the femur by strong, flat tendons. The medial and larger head takes its origin from a depression at the upper and posterior part of the medial condyle behind the adductor tubercle, and from a rounded tubercle on the popliteal surface of the femur just above the medial condyle. The lateral head arises from an impression on the lateral surface of the lateral condyle and from the lower part of the corresponding epicondylar ridge. Both heads also arise from the subjacent part of the articular capsule of the knee joint. Each head spreads out into a tendinous expansion which covers the posterior surface of the corresponding part of the muscle. From the anterior surfaces of these tendinous expansions, muscular fibres are given off; those of the medial head being thicker and extending lower than those of the lateral

2. The Medial Volar Muscles (figs. 588, 589)

Palmaris brevis.
Abductor digiti quinti.
Flexor digiti quinti brevis.
Opponens digiti quinti.

The **Palmaris brevis** (fig. 587) is a thin, quadrilateral muscle, placed beneath the skin of the ulnar side of the hand. It arises by tendinous fasciculi

Fig. 589.—The muscles of the left hand. Volar aspect.



from the transverse carpal ligament and palmar aponeurosis; the fleshy fibres are inserted into the skin on the proximal part of the ulnar border of the hand.

Nerve-supply.—The Palmaris brevis is supplied by the eighth cervical nerve through the ulnar nerve.

about 15 cm. long, and begins near the middle of the leg, but receives fleshy fibres on its anterior surface, almost to its lower end. It gradually narrows and thickens until it reaches a level about 4 cm. above the calcaneus; below this level it expands and is inserted into the middle part of the posterior surface of the calcaneus, a bursa being interposed between the tendon and the upper part of this surface.

Actions.—The muscles of the calf—Gastrocnemius and Soleus—are the chief extensors of the ankle-joint. They possess considerable power, and are called into use in standing, walking, dancing, and leaping; hence the large size they usually present. In walking, these muscles raise the heel from the ground; the body being thus supported on the raised foot, the opposite limb can be carried forwards.

The **Plantaris** (fig. 611) arises from the lower part of the lateral prolongation of the linea aspera, and from the oblique popliteal ligament of the knee-joint. It forms a small fusiform belly, from 7 cm. to 10 cm. long; this ends in a long slender tendon which crosses obliquely between the Gastrocnemius and Soleus, and runs along the medial border of the tendo calcaneus, to be inserted with it into the posterior part of the calcaneus. This muscle is sometimes double, and at other times wanting. Occasionally, its tendon is lost in the laciniate ligament, or in the fascia of the leg.

Nerve-supply.—The Plantaris is supplied by the fourth and fifth lumbar and first sacral nerves, through the tibial nerve.

Actions.—The Plantaris is the rudiment of a large muscle, the tendon of which in some of the lower animals is inserted into the plantar aponeurosis: in man it is an accessory to the Gastrocnemius, extending the ankle-joint if the foot be free, or flexing the knee-joint if the foot be fixed.

Deep Group (fig. 612)

Popliteus.	Flexor digitorum longus.
Flexor hallucis longus.	Tibialis posterior.

The **deep transverse fascia** of the leg is a septum between the superficial and deep muscles of the back of the leg. At the sides it is connected to the medial margin of the tibia and the posterolateral border of the fibula. Above, where it covers the Popliteus, it is thick and dense, and receives an expansion from the tendon of the Semimembranosus; it is thin in the middle of the leg; but below, where it covers the tendons passing behind the malleoli, it is thick and continuous with the laciniate ligament.

The **Popliteus** (fig. 612) is a thin, flat, triangular muscle, which forms the floor of the lower part of the popliteal fossa. It arises by a strong tendon about 2·5 cm. long, from a depression at the anterior part of the groove on the lateral condyle of the femur, and to a small extent from the oblique popliteal ligament of the knee-joint. It is inserted into the medial two-thirds of the triangular surface above the popliteal line on the posterior surface of the body of the tibia, and into the tendinous expansion covering the muscle.

Relations.—Its tendon of origin is covered by the tendon of the Biceps femoris and by the fibular collateral ligament of the knee-joint: it grooves the posterior border of the lateral meniscus, and is invested by the synovial stratum of the capsule of the knee-joint. The fascia covering the muscle separates it from the Gastrocnemius, Plantaris, popliteal vessels, and tibial nerve. The deep surface of the muscle is in contact with the oblique popliteal ligament of the knee-joint and the back of the tibia.

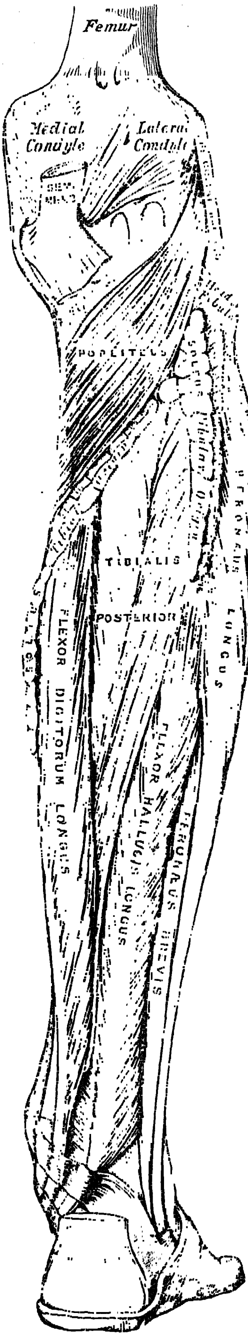
Nerve-supply.—The Popliteus is supplied by the fourth and fifth lumbar and first sacral nerves, through the tibial nerve.

Actions.—The Popliteus flexes the knee-joint; when the joint is flexed, it rotates the tibia inwards. It is specially called into action at the beginning of flexion of the knee-joint inasmuch as it produces the slight inward rotation of the tibia which is essential in the early stage of this movement.

The **Flexor hallucis longus** (figs. 612, 615) is situated on the fibular side of the leg. It arises from the inferior two-thirds of the posterior surface of the body of the fibula, with the exception of about 2·5 cm. at its lowest part; from the lower part of the interosseous membrane; from the posterior fibular intermuscular septum, and from the fascia covering the Tibialis posterior. The fibres pass obliquely downwards and backwards, and end in a tendon which occupies nearly the whole length of the posterior surface of the muscle. This tendon lies

in a groove which crosses the posterior surface of the lower end of the tibia, the posterior surface of the talus, and the under surface of the sustentaculum tali of the calcaneus. In the sole of the foot it runs forwards between the two heads of the Flexor hallucis brevis, and is inserted into the base of the distal phalanx of the great toe. The grooves on the talus and calcaneus, which contain the tendon of the muscle, are converted by tendinous fibres into a canal which is lined by a mucous sheath. As the tendon passes forwards in the sole of the foot, it is situated above, and crosses from the lateral to the medial side of, the tendon of the Flexor digitorum longus, to which it is connected by a fibrous slip.

Fig. 612.—The right posterior crural muscles. Deep group.



Relations.—Its *superficial surface* is in relation with the Soleus and tendo calcaneus, from which it is separated by the deep transverse fascia; its *deep surface*, with the fibula, Tibialis posterior, the peronæal vessels, the lower part of the interosseous membrane, and the ankle-joint: its *lateral border*, with the Peronæi; its *medial border*, with the Tibialis posterior, posterior tibial vessels and tibial nerve.

Nerve-supply.—The Flexor hallucis longus is supplied by the fifth lumbar and first and second sacral nerves, through the tibial nerve.

Actions.—The Flexor hallucis longus flexes the great toe, and, continuing its action, extends the ankle-joint.

The **Flexor digitorum longus** (fig. 612) is situated on the tibial side of the leg. At its origin it is thin and pointed, but it gradually increases in size as it descends. It arises from the posterior surface of the body of the tibia, medial to the tibial origin of the Tibialis posterior; this origin extends from immediately below the popliteal line to within 7 cm. or 8 cm. of the lower extremity of the bone; it also arises from the fascia covering the Tibialis posterior. The fibres end in a tendon, which runs nearly the whole length of the posterior surface of the muscle. This tendon passes behind the medial malleolus, in a groove common to it and the Tibialis posterior, but separated from the latter by a fibrous septum; each tendon being contained in a special compartment lined by a separate mucous sheath. It passes obliquely forwards and lateralwards, in contact with the medial side of the sustentaculum tali (fig. 613), and deep to the laciniate ligament, and enters the sole of the foot (fig. 620), where it crosses below (i.e. superficial to) the tendon of the Flexor hallucis longus, and receives from it a strong slip. It then expands and is joined by the Quadratus plantæ, and finally divides into four tendons, which are inserted into the bases of the last phalanges of the second, third, fourth, and fifth toes, each tendon passing through an opening in the corresponding tendon of the Flexor digitorum brevis opposite the base of the first phalanx.

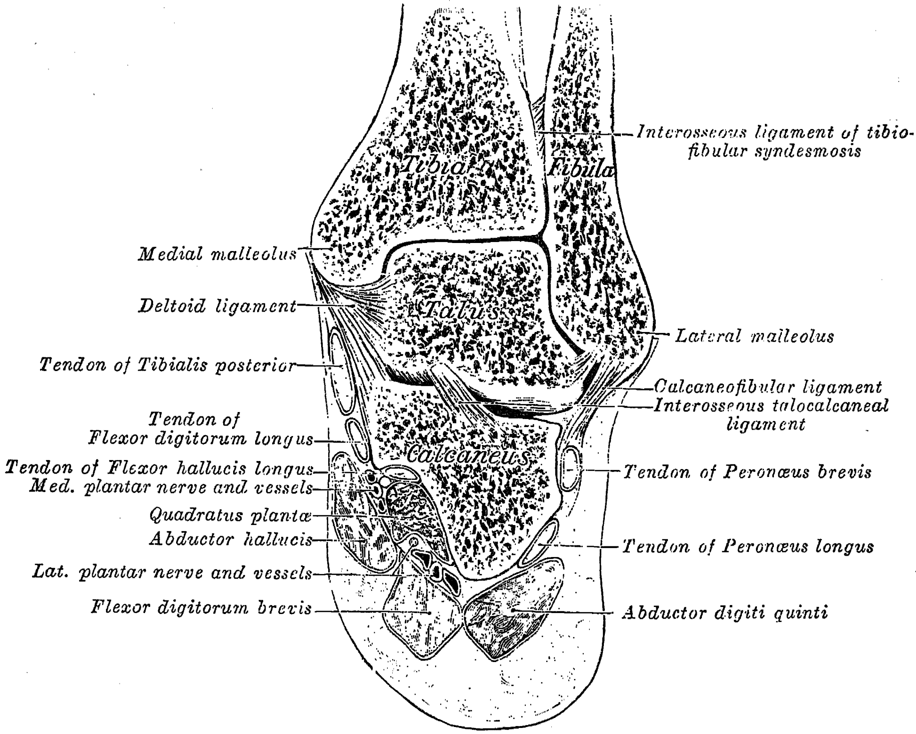
Relations.—In the leg its *superficial surface* is in relation with the posterior tibial vessels and tibial nerve, and the deep transverse fascia which separates it from the Soleus; its *deep surface*, with the tibia and Tibialis posterior. In the foot, it is covered

by the Abductor hallucis and Flexor digitorum brevis, and crosses superficial to the Flexor hallucis longus.

Nerve-supply.—The Flexor digitorum longus is supplied by the fifth lumbar and first sacral nerves through the tibial nerve.

Actions.—The Flexor digitorum longus flexes the phalanges of the toes, and in continued action extends the ankle-joint. In consequence of the oblique direction of its tendons it draws the toes medialwards, but this is counteracted by the Quadratus plantæ which is inserted into the lateral side of the tendon.

FIG. 613.—A coronal section through the right talocrural and talocalcaneal joints.



The **Tibialis posterior** (figs. 609, 612) lies between the Flexor hallucis longus and Flexor digitorum longus, and is the deepest muscle on the back of the leg. It begins above by two pointed processes, separated by an angular interval through which the anterior tibial vessels pass to the front of the leg. It arises from the posterior surface of the crural interosseous membrane, with the exception of its lowest part; from the lateral portion of the posterior surface of the body of the tibia, between the commencement of the popliteal line above and the junction of the middle with the lower one-third of the body below; and from the upper two-thirds of the medial surface of the fibula; some fibres also arise from the deep transverse fascia, and from the intermuscular septa separating it from the adjacent muscles. In the lower one-fourth of the leg its tendon passes in front of that of the Flexor digitorum longus and lies with it in a groove behind the medial malleolus, but enclosed in a separate sheath; it next passes under the laciniate and over the deltoid ligament into the foot, and then below the plantar calcaneonavicular ligament, where it contains a sesamoid fibrocartilage. It is inserted into the tuberosity of the navicular bone, and gives off fibrous slips, one of which passes backwards and is attached to the sustentaculum tali of the calcaneus, while others pass forwards and lateralwards and are fixed to the three cuneiform bones, the cuboid bone, and the bases of the second, third, and fourth metatarsal bones.

Relations.—Its *superficial surface* is in relation with the Soleus, from which it is separated by the deep transverse fascia, the Flexor digitorum longus, the posterior tibial vessels and tibial nerve, and the peronæal vessels; its *deep surface* with the interosseous membrane, the tibia, fibula, and ankle-joint.

Nerve-supply.—The Tibialis posterior is supplied by the fifth lumbar and first sacral nerves through the tibial nerve.

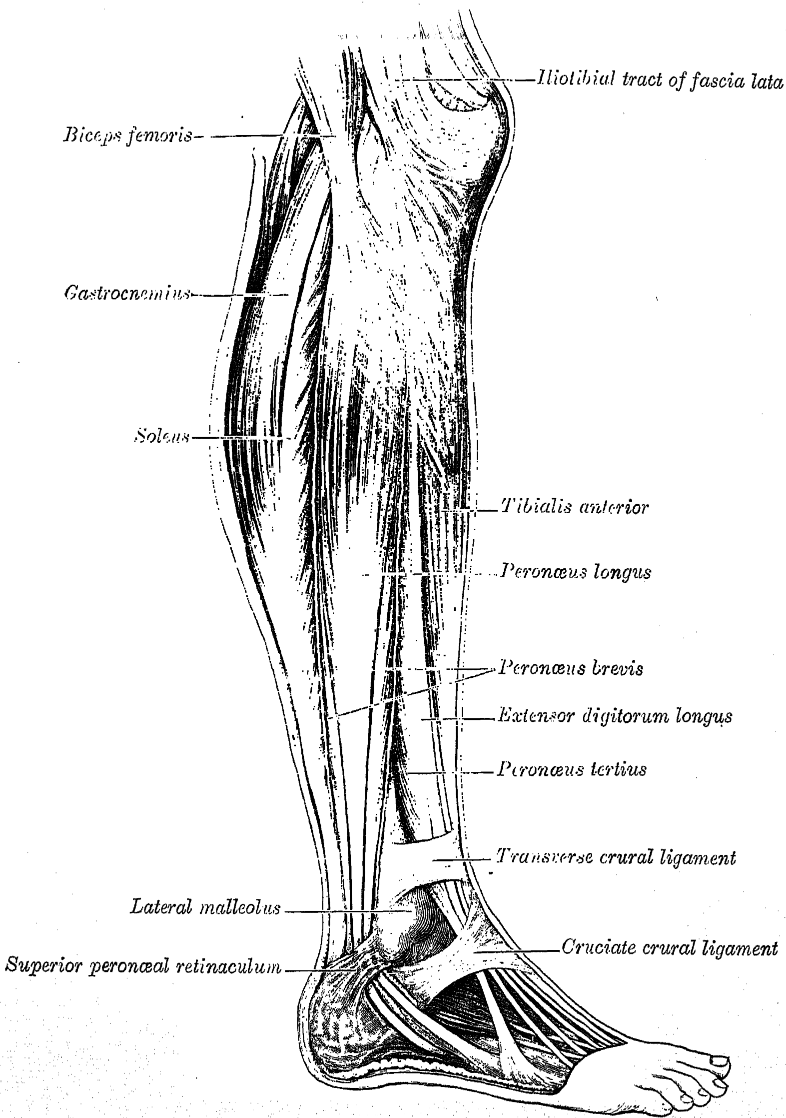
Actions.—The Tibialis posterior extends the ankle-joint; it also pulls up the medial border of the foot, i.e. inverts the foot. In the sole of the foot its tendon lies directly below the plantar calcaneonavicular ligament, and is an important factor in maintaining the longitudinal arch of the foot.

3. The Lateral Crural Muscles (fig. 614)

Peronæus longus. Peronæus brevis.

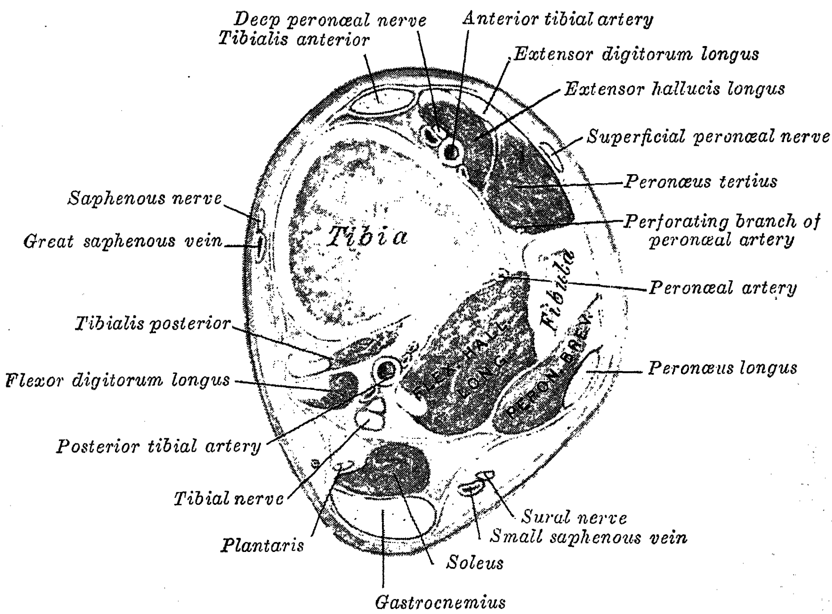
The **Peronæus longus** (figs. 609, 612, 614) is situated at the upper part of the lateral side of the leg, and is the more superficial of the two muscles. It arises from the head and upper two-thirds of the lateral surface of the body of the

Fig. 614.—The right lateral crural muscles.



fibula, from the deep surface of the fascia, and from the anterior and posterior fibular intermuscular septa : occasionally also by a few fibres from the lateral condyle of the tibia. Between its attachments to the head and body of the fibula there is a gap through which the common peronæal nerve passes to the front of the leg. It ends in a long tendon, which runs behind the lateral malleolus, in a groove common to it and the tendon of the Peronæus brevis, behind which it lies ; the groove is converted into a canal by the superior peronæal retinaculum, and the tendons in it are contained in a common mucous sheath. The tendon then extends obliquely forwards across the lateral side of the calcaneus, below the trochlear process and the tendon of the Peronæus brevis, and under cover of the inferior peronæal retinaculum ; it crosses the lateral side of the cuboid bone, and then runs on the under surface of that bone in a groove which is converted into a canal by the long plantar ligament.

FIG. 615.—A transverse section through the leg, 6 cm. proximal to the tip of the medial malleolus.



It then crosses the sole of the foot obliquely, and is inserted by two slips into (*a*) the lateral side of the base of the first metatarsal bone and (*b*) the lateral side of the first cuneiform bone; occasionally a third slip is attached to the base of the second metatarsal bone. The tendon changes its direction at two points: (*a*) below the lateral malleolus, (*b*) on the cuboid bone; in both of these situations it is thickened, and, in the latter, a sesamoid fibro-cartilage (sometimes a bone) is usually developed in its substance.

Nerve-supply.—The Peronæus longus is supplied by the fourth and fifth lumbar and first sacral nerves through the superficial peronæal nerve.

Actions.—The Peronæus longus extends the ankle-joint and everts the foot. As a consequence of the oblique direction of its tendon across the sole it is an important agent in maintaining the transverse arch of the foot. Taking its fixed point below, the Peronæus longus serves to steady the leg on the foot; this is especially the case in standing on one leg, when the tendency of the superincumbent weight is to throw the leg medialwards; the Peronæus longus overcomes this tendency by drawing on the lateral side of the leg.

The **Peronæus brevis** (figs. 614, 615) arises from the lower two-thirds of the lateral surface of the body of the fibula, in front of the Peronæus longus; and from the anterior and posterior fibular intermuscular septa. The fibres pass vertically downwards, and end in a tendon which runs behind the lateral

malleolus along with, but in front of, that of the Peronæus longus, the two tendons being enclosed in the same compartment, and lubricated by a common mucous sheath. It then runs forwards on the lateral side of the calcaneus, above the trochlear process and the tendon of the Peronæus longus, and is inserted into the tuberosity at the base of the fifth metatarsal bone, on its lateral side.

On the lateral surface of the calcaneus the tendons of the Peronæi longus et brevis occupy separate osseo-aponeurotic canals formed by the calcaneus and the inferior peronæal reticulum; each tendon is enveloped by a forward prolongation of the common mucous sheath.

Nerves.—The Peronæus brevis is supplied by the fourth and fifth lumbar and first sacral nerves through the superficial peronæal nerve.

Action.—The Peronæus brevis extends the foot upon the leg.

Applied Anatomy.—Rigidity and contraction of the tendons of the various muscles of the leg give rise to one or other of the kinds of deformity known as *club foot*. The most simple and common deformity, and one that is rarely, if ever, congenital, is *talipes equinus*, the heel being raised by the rigidity and contraction of the Gastrocnemius so that the patient walks upon the ball of the foot. A condition of temporary talipes equinus is often produced by the weight of the bed-clothes in patients, particularly children, who have been kept lying on their backs in bed for a few weeks. In these cases unless a cradle is used to protect the feet, the weight of the bed-clothes will often keep them extended, causing a temporary shortening of the calf-muscles that will prevent the patient from flexing the ankles to anything less than a right angle, and will produce a characteristic shuffling gait when he first gets up and walks. In *talipes varus*, the foot is forcibly adducted and the medial side of the sole raised, sometimes to a right angle with the ground, by the action of the Tibiales anterior et posterior. In *talipes valgus*, the lateral edge of the foot is raised by the Peronæi, and the patient walks on the medial side of the foot. In *talipes calcaneus* the toes are raised by the extensor muscles, the heel is depressed and the patient walks upon it. Other varieties of deformity are met with, as *talipes equinovarus*, *equinovalgus*, and *calcaneovalgus*, names which sufficiently indicate their nature. Of these, talipes equinovarus is the most common congenital form; the heel is raised by the tendo calcaneus, the medial border of the foot drawn upwards by the Tibialis anterior, the anterior two-thirds twisted medialwards by the Tibialis posterior, and the arch increased by the contraction of the plantar aponeurosis, so that the patient walks on the middle of the lateral border of the foot. Each of these deformities may sometimes be successfully relieved by division of the opposing tendons and fascia; by this means the foot regains its proper position, and the tendons heal by the organisation of lymph thrown out between the divided ends. The operation is easily performed by putting the contracted tendon upon the stretch, and dividing it by means of a narrow, sharp-pointed knife inserted beneath it.

Rupture of a few of the fibres of the Gastrocnemius, or rupture of the Plantaris tendon, not uncommonly occurs, especially in men somewhat advanced in life, from some sudden exertion, and frequently occurs during the game of lawn-tennis, and is hence known as 'lawn-tennis leg.' The accident is accompanied by a sudden pain, and produces a sensation as if the individual had been struck a violent blow on the part. The tendo calcaneus is also sometimes ruptured. It is stated that John Hunter ruptured his tendo calcaneus while dancing, at the age of forty. The bursa between the tendo calcaneus and the posterior surface of the calcaneus sometimes becomes inflamed, especially in pedestrians and 'long-distance' walkers. It causes great and disabling pain, and entirely prevents the sufferer from continuing his walk.

THE FASCIA ROUND THE ANKLE

Fibrous bands, thickened portions of fascia, bind down the tendons in front of and behind the ankle in their passage to the foot. They comprise the transverse crural, cruciate crural, and laciniate ligaments, and the superior and inferior peronæal retinacula.

The **transverse crural ligament** (upper part of anterior annular ligament) (figs. 610, 616) binds down the tendons of the Tibialis anterior, Extensor hallucis longus, Extensor digitorum longus and Peronæus tertius as they descend on the front of the tibia and fibula; the anterior tibial vessels and the deep peronæal nerve also pass under cover of it. It is attached laterally to the lower end of the fibula, and medially to the tibia; above, it is continuous with the fascia of the leg.

The **cruciate crural ligament** (lower part of anterior annular ligament) (figs. 610, 616) is a Y-shaped band placed in front of the ankle-joint. The stem of the Y is attached to the upper surface of the calcaneus, in front of the sulcus calcanei ; it is directed medialwards in front of the tendons of the

FIG. 616.—The mucous sheaths of the tendons round the right ankle. Lateral aspect. (From a specimen prepared by J. C. B. Grant.)

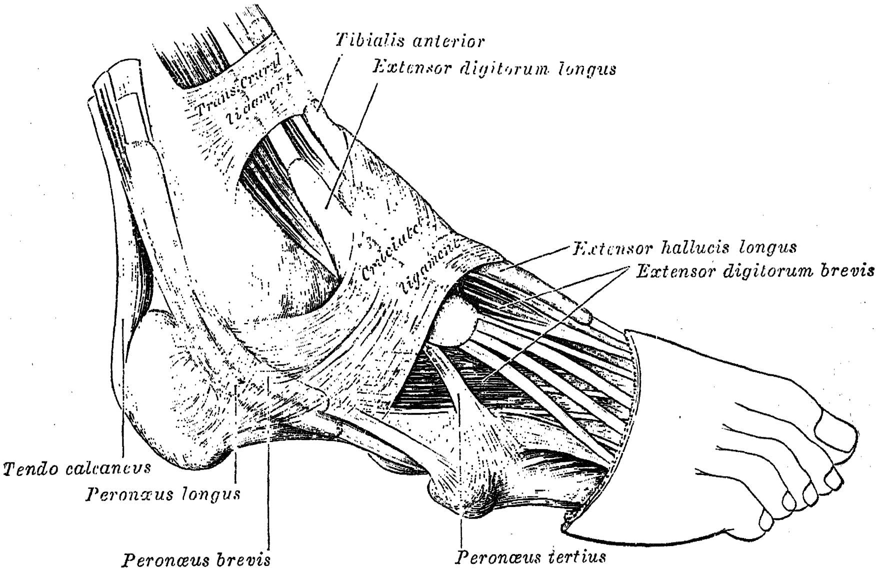
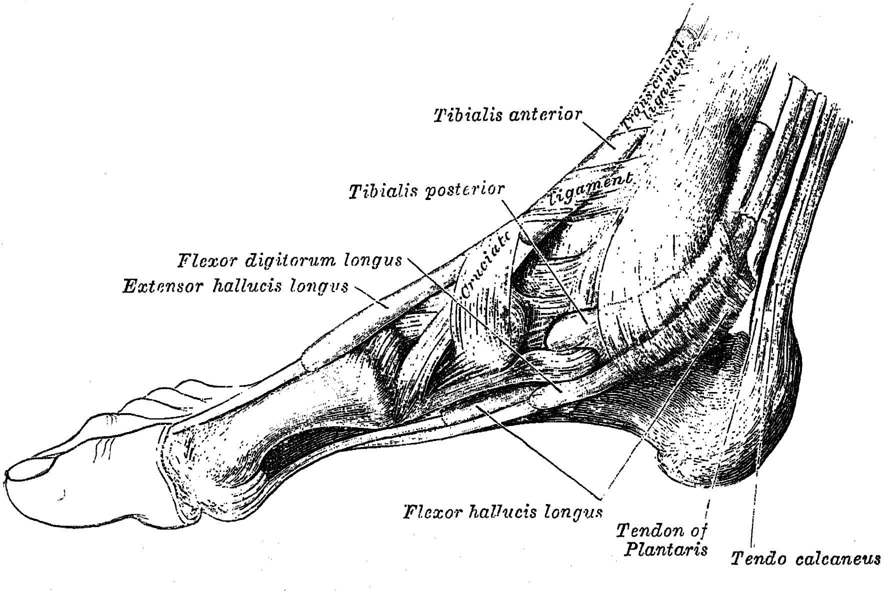


FIG. 617.—The mucous sheaths of the tendons round the right ankle. Medial aspect. (From a specimen prepared by J. C. B. Grant.)



Peronæus tertius and Extensor digitorum longus and divides into two limbs. One limb is directed upwards and medialwards, to be attached to the tibial malleolus, passing over the Extensor hallucis longus and the anterior tibial vessels and deep peronæal nerve, but enclosing the Tibialis anterior by splitting into two laminæ. The other limb extends downwards and medialwards to be

attached to the plantar aponeurosis; it crosses the tendons of the Extensor hallucis longus and Tibialis anterior, the arteria dorsalis pedis, and the terminal branches of the deep peronæal nerve.

The **laciniate ligament** (internal annular ligament) extends from the tibial malleolus above to the margin of the calcaneus below; its upper border is continuous with the deep fascia of the leg, its lower with the plantar aponeurosis and the fibres of origin of the Abductor hallucis muscle. It converts a series of bony grooves in this situation into canals for the passage of the tendons of the flexor muscles into the sole of the foot and also affords protection to the posterior tibial vessels and tibial nerve as they enter the sole of the foot. From the medial to the lateral side, these structures lie in the following order: tendon of the Tibialis posterior, tendon of the Flexor digitorum longus, posterior tibial vessels and tibial nerve, and tendon of the Flexor hallucis longus.

The **peronæal retinacula** are fibrous bands which retain the tendons of the Peronæi longus et brevis in position as they cross the lateral side of the ankle. The *superior retinaculum* (external annular ligament) is attached above to the lateral malleolus and below to the lateral surface of the calcaneus. The *inferior retinaculum* is continuous in front with the cruciate crural ligament; behind it is attached to the lateral surface of the calcaneus; some of its fibres are fixed to the trochlear process of the calcaneus, forming a septum between the tendons of the Peronæi longus et brevis.

The **mucous sheaths of the tendons round the ankle.**—The tendons crossing the ankle-joint are enclosed in mucous sheaths. On the *front* of the ankle (fig. 616) the sheath for the Tibialis anterior extends from the upper margin of the transverse crural ligament to the interval between the diverging limbs of the cruciate ligament; those for the Extensor digitorum longus and Extensor hallucis longus reach upwards to just above the level of the malleoli, the former being the higher. The sheath of the Extensor hallucis longus is prolonged on to the base of the first metatarsal bone, while that of the Extensor digitorum longus reaches only to the level of the base of the fifth metatarsal bone. On the *medial side* of the ankle (fig. 617) the sheath for the Tibialis posterior extends for about 4 cm. above the malleolus; below, it ends just short of the insertion of the tendon into the tuberosity of the navicular bone. The sheath for the Flexor hallucis longus reaches up to the level of the malleolus, while that for the Flexor digitorum longus is slightly higher; the former is continued to the base of the first metatarsal bone, but the latter ends opposite the navicular bone.

On the *lateral side* of the ankle (fig. 616) a sheath, which is single for the greater part of its extent, encloses the Peronæi longus et brevis. It extends upwards for about 4 cm. above the tip of the malleolus and downwards and forwards for about the same distance.

IV. The Muscles of the Foot

1. The Dorsal Muscle of the Foot

Extensor digitorum brevis

The **fascia** on the dorsum of the foot (fascia dorsalis pedis) is a thin membranous layer, continuous above with the transverse and cruciate crural ligaments; on either side it blends with the plantar aponeurosis; anteriorly it forms a sheath for the tendons on the dorsum of the foot.

The **Extensor digitorum brevis** (figs. 610, 616) is a thin muscle, which arises from the forepart of the upper and lateral surface of the calcaneus, in front of the groove for the Peronæus brevis; from the lateral talocalcaneal ligament, and the stem of the cruciate crural ligament. It passes obliquely forwards and medialwards across the dorsum of the foot, and ends in four tendons. The medial part of the muscle is usually a more or less distinct slip ending in a tendon which crosses the dorsalis pedis artery and is inserted into the dorsal surface of the base of the first phalanx of the great toe; it is sometimes described as a separate muscle—the *Extensor hallucis brevis*. The

other three tendons are inserted into the lateral sides of the tendons of the Extensor digitorum longus of the second, third, and fourth toes.

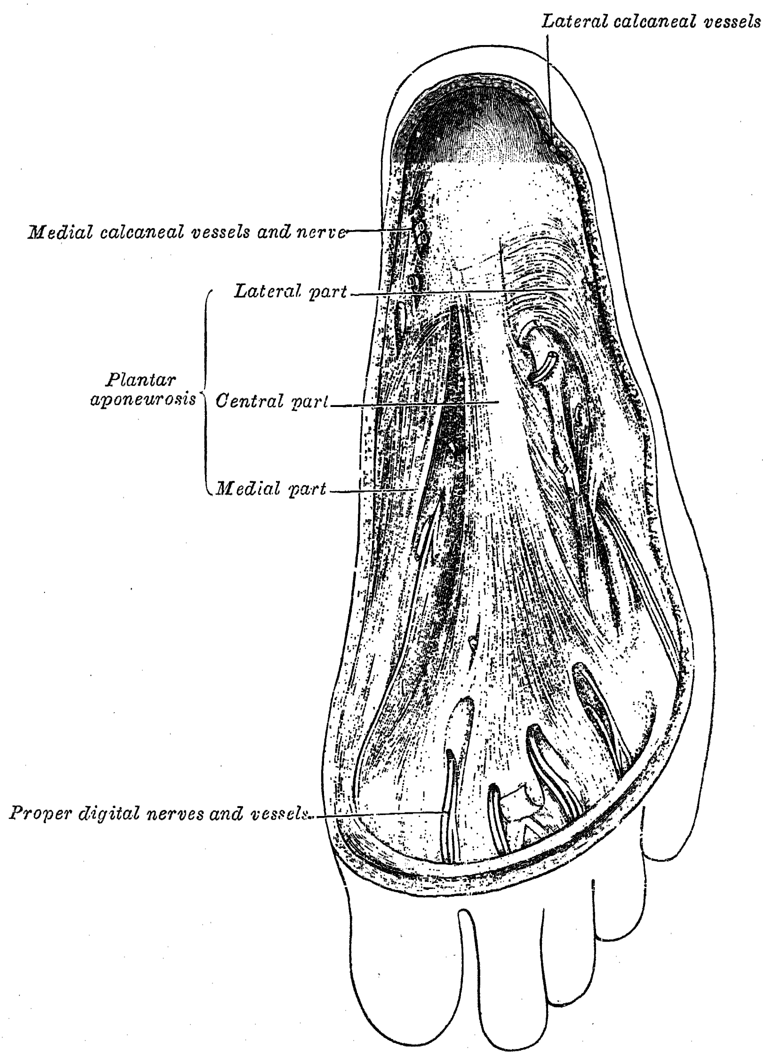
Nerve-supply.—The Extensor digitorum brevis is supplied by the fourth and fifth lumbar and first sacral nerves through the deep peronæal nerve.

Actions.—The Extensor digitorum brevis extends the phalanges of the four toes into which it is inserted, but, in the great toe, acts only on the first phalanx.

2. The Plantar Muscles of the Foot

The **plantar aponeurosis** (fig. 618) is of great strength, and consists of white fibres disposed, for the most part, longitudinally: it is divided into central, lateral, and medial portions.

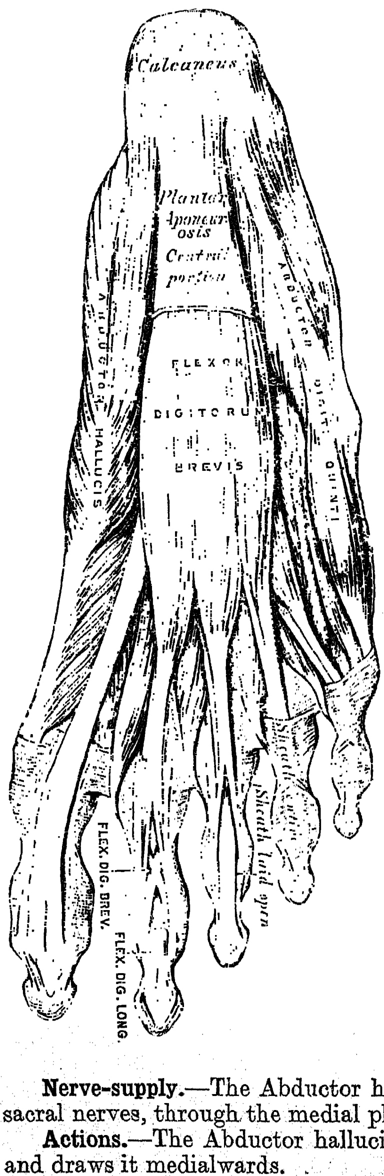
Fig. 618.—The plantar aponeurosis of the right foot.



The *central portion*, the thickest, is narrow behind, and attached to the medial process of the tuberosity of the calcaneus, posterior to the origin of the Flexor digitorum brevis; it becomes broader and thinner in front, and divides near the heads of the metatarsal bones into five processes, one for each of the toes. Each of these processes splits opposite the metatarsophalangeal articulation into two strata, superficial and deep. The superficial stratum

is inserted into the skin of the transverse sulcus which separates the toes from the sole. The deep stratum divides into two slips which embrace the sides of the flexor tendons of the toes, and blend with the sheaths of the tendons, and with the transverse metatarsal ligament, thus forming a series of arches through which the tendons of the short and long flexors pass to the toes. Through the intervals between the five processes the digital vessels and nerves and the tendons of the Lumbricales are transmitted. At the point of division of the aponeurosis are numerous transverse fasciculi which bind the processes together, and connect them with the integument. The central portion of the plantar aponeurosis is continuous with the lateral and medial portions, and sends upwards into the foot, at the lines of junction, two vertical intermuscular septa, which separate the intermediate from the lateral and medial groups of plantar muscles; from these vertical septa thinner transverse septa are derived which separate the different layers of muscles in this region. The deep surface of the central part of the aponeurosis gives origin behind to the Flexor digitorum brevis.

Fig. 619.—The plantar muscles of the right foot. First layer.



The *lateral portion* covers the under surface of the Abductor digiti quinti; it is thin in front and thick behind, where it forms a strong band between the lateral process of the tuberosity of the calcaneus and the base of the fifth metatarsal bone; it is continuous medially with the central portion, and laterally with the fascia dorsalis pedis.

The *medial portion* is thin, and covers the under surface of the Abductor hallucis; it is continuous behind with the laciniate ligament, medially with the fascia dorsalis pedis, and laterally with the central portion of the plantar aponeurosis.

The muscles in the plantar region of the foot may be divided into medial, lateral and intermediate groups; but for descriptive purposes it is more convenient to divide them into four layers, in the order in which they are successively exposed in dissecting this region.

The First Layer (fig. 619)

Abductor hallucis.
Flexor digitorum brevis.
Abductor digiti quinti.

The **Abductor hallucis** (fig. 619) lies along the medial border of the foot and covers the origins of the plantar vessels and nerves. It arises from the medial process of the tuberosity of the calcaneus, the laciniate ligament, the plantar aponeurosis, and the intermuscular septum between it and the Flexor digitorum brevis. The fibres end in a tendon which is inserted, together with the medial tendon of the Flexor hallucis brevis, into the medial side of the base of the first phalanx of the great toe.

Nerve-supply.—The Abductor hallucis is supplied by the fifth lumbar and first sacral nerves, through the medial plantar nerve.

Actions.—The Abductor hallucis flexes the proximal phalanx of the great toe and draws it medialwards.

The **Flexor digitorum brevis** (fig. 619) lies immediately above the central part of the plantar aponeurosis. Its deep surface is separated from the lateral plantar vessels and nerves by a thin layer of fascia. It arises by a narrow tendon, from the medial process of the tuberosity of the calcaneus, from the central part of the plantar aponeurosis, and from the intermuscular septa between it and the adjacent muscles. It divides into four tendons, one for each of the four lesser toes. Opposite the bases of the first phalanges, each tendon divides into two slips, to allow of the passage of the corresponding tendon of the Flexor digitorum longus; the two slips then unite, partially decussate, and form a grooved channel for the reception of the tendon of the Flexor digitorum longus. The tendon divides again and is inserted into the sides of the second phalanx about its middle. The mode of division of the tendons of the Flexor digitorum brevis, and of their insertion into the phalanges, is analogous to that of the tendons of the Flexor digitorum sublimis in the hand.

Nerve-supply.—The Flexor digitorum brevis is supplied by fifth lumbar and first sacral nerves, through the medial plantar nerve.

Actions.—The Flexor digitorum brevis flexes the second phalanges upon the first; continuing its action it flexes the first phalanges and brings the toes together.

The **fibrous sheaths of the flexor tendons** (fig. 619).—The terminal portions of the tendons of the long and short flexor muscles are contained in osseo-aponeurotic canals similar in their arrangement to those in the fingers. These canals are bounded above by the phalanges, and below by fibrous bands, which arch across the tendons, and are attached on either side to the margins of the phalanges. Opposite the bodies of the proximal and second phalanges the fibrous bands (*vaginal ligaments*) are strong, and the fibres are transverse; but opposite the joints they are much thinner, and the fibres are directed obliquely. Each canal contains a mucous sheath, which is reflected on the contained tendons; within this sheath are *vincula tendinum* arranged similarly to those of the fingers.

The **Abductor digiti quinti** (fig. 619) lies along the lateral border of the foot, and its medial margin is in relation with the lateral plantar vessels and nerve. It arises from the lateral and medial processes of the tuberosity of the calcaneus, from the under surface of the bone between the processes, from the plantar aponeurosis, and from the intermuscular septum between it and the Flexor digitorum brevis. Its tendon glides over a smooth facet on the under surface of the base of the fifth metatarsal bone and is inserted, with the Flexor digiti quinti brevis, into the lateral side of the base of the first phalanx of the fifth toe.

Nerve-supply.—The Abductor digiti quinti is supplied by the first and second sacral nerves through the lateral plantar nerve.

Actions.—The Abductor digiti quinti flexes the proximal phalanx of the little toe and draws it lateralwards.

The Second Layer (fig. 620)

Quadratus plantæ. Lumbricales.

The **Quadratus plantæ** (Flexor accessorius) (fig. 620) arises by two heads, which are separated from each other by the long plantar ligament: the medial, the larger, head is muscular, and is attached to the medial concave surface of the calcaneus, below the groove for the tendon of the Flexor hallucis longus; the lateral head, flat and tendinous, arises from the calcaneus in front of the lateral process of its tuberosity, and from the long plantar ligament. The two portions join at an acute angle, and end in a flattened band which is inserted into the inferior surface and lateral margin of the tendon of the Flexor digitorum longus, forming a kind of groove in which the tendon is lodged. It usually sends slips to those tendons of the Flexor digitorum longus which pass to the second, third, and fourth toes.

Nerve-supply.—The Quadratus plantæ is supplied by the first and second sacral nerves, through the lateral plantar nerve.

Actions.—The Quadratus plantæ assists the Flexor digitorum longus and converts the oblique pull of the tendons of that muscle into a direct backward pull on the toes.

The **Lumbricales** (fig. 620) are four small muscles, accessory to the tendons of the Flexor digitorum longus, and numbered from the medial side of the foot; they arise from these tendons, as far back as their angles of separation, each springing from two tendons, except the first, which arises only from the medial border of the first tendon of the Flexor digitorum longus. The muscles end in tendons, which pass forwards on the medial sides of the four lesser toes, and are inserted into the expansions of the tendons of the Extensor digitorum longus on the dorsal surfaces of the first phalanges.

Fig. 620.—The plantar muscles of the right foot. Second layer.

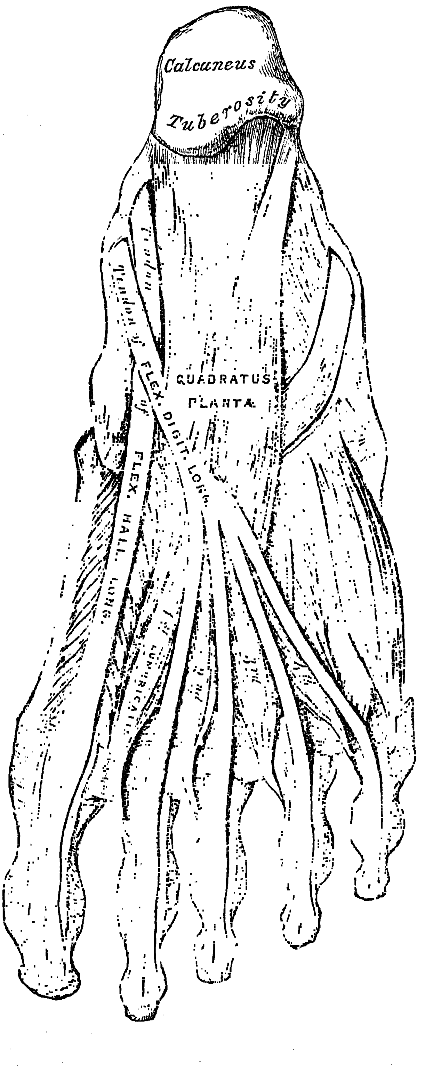
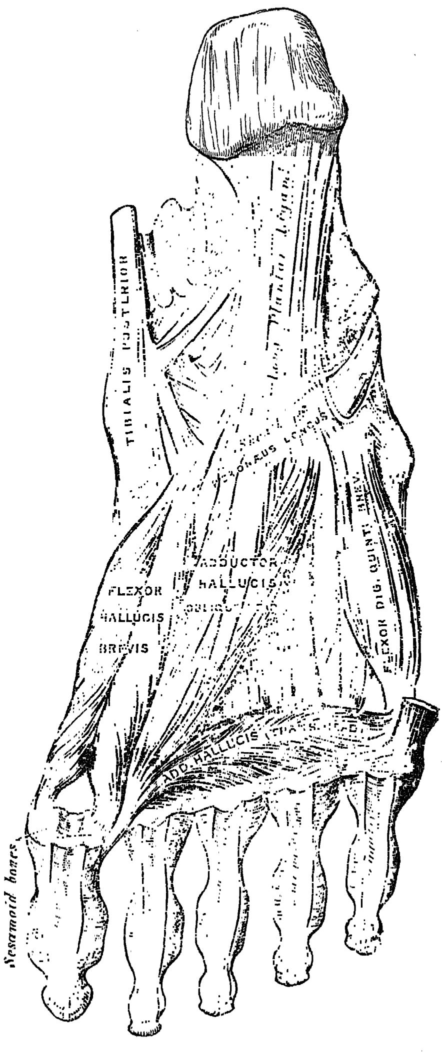


Fig. 621.—The plantar muscles of the right foot. Third layer.



Nerve-supply.—The first Lumbricalis is supplied by the fifth lumbar and first sacral nerves through the medial plantar nerve; the others by the first and second sacral nerves through the lateral plantar nerve.

Actions.—The Lumbricales flex the proximal phalanges, and by their insertions into the tendons of the Extensor digitorum longus, extend the middle and terminal phalanges.

The Third Layer (fig. 621)

Flexor hallucis brevis. Adductor hallucis.
Flexor digiti quinti brevis.

The **Flexor hallucis brevis** (fig. 621) arises by a pointed tendinous process from the medial part of the under surface of the cuboid bone, from the contiguous portion of the third cuneiform bone, and from the part of the tendon of the Tibialis posterior which is attached to that bone. It divides into a medial and a lateral portion, and the tendons of these are inserted into the corresponding sides of the base of the first phalanx of the great toe, a sesamoid bone being present in each tendon at its insertion. The medial portion is blended with the Abductor hallucis previous to its insertion; the lateral with the Adductor hallucis. The lateral portion of the Flexor hallucis brevis is sometimes described as the *first plantar interosseous* muscle.

Nerve-supply.—The Flexor hallucis brevis is supplied by the fifth lumbar and first sacral nerves, through the medial plantar nerve.

Action.—The Flexor hallucis brevis flexes the proximal phalanx of the great toe.

The **Adductor hallucis** (fig. 621) arises by two heads—oblique and transverse. The *oblique head* springs from the bases of the second, third, and fourth metatarsal bones, and from the sheath of the tendon of the Peronæus longus, and is inserted, together with the lateral portion of the Flexor hallucis brevis, into the lateral side of the base of the first phalanx of the great toe. The *transverse head* (Transversus pedis), a narrow, flat fasciculus, arises from the plantar metatarsophalangeal ligaments of the third, fourth, and fifth toes (sometimes only from the third and fourth), and from the transverse metatarsal ligament. It is inserted into the lateral side of the base of the first phalanx of the great toe, its tendon of insertion blending with that of the oblique head.

Nerve-supply.—The Adductor hallucis is supplied by the first and second sacral nerves, through the lateral plantar nerve.

Actions.—The oblique head of the Adductor hallucis is chiefly concerned in adducting, but it also assists in flexing, the great toe; the transverse head approximates the toes and thus increases the curve of the transverse arch of the metatarsus.

The **Flexor digiti quinti brevis** (fig. 621) arises from the base of the fifth metatarsal bone, and from the sheath of the Peronæus longus; its tendon is inserted into the lateral side of the base of the first phalanx of the fifth toe. Occasionally a few of the deeper fibres are inserted into the lateral part of the distal one-half of the fifth metatarsal bone; these are described by some as a distinct muscle, the *Opponens digiti quinti.*

Nerve-supply.—The Flexor digiti quinti brevis is supplied by the first and second sacral nerves, through the lateral plantar nerve.

Action.—The Flexor digiti quinti brevis flexes the little toe.

The Fourth Layer.

Interossei.

The **Interossei** in the foot are similar to those in the hand, but are grouped on either side of the middle line of the *second* digit, instead of that of the *third.* They consist of a dorsal and a plantar set.

The **Interossei dorsales** (fig. 622), four in number, are situated between the metatarsal bones. They are bipennate muscles, each arising by two heads from the adjacent sides of the metatarsal bones between which it is placed; their tendons are inserted into the bases of the first phalanges, and into the aponeuroses of the tendons of the Extensor digitorum longus. The first is inserted into the medial side of the second toe; the other three into the lateral sides of the second, third, and fourth toes. In the angular interval between the heads of each of the three lateral muscles, one of the perforating arteries passes to the dorsum of the foot; through the space between the heads of the first muscle the deep plantar branch of the dorsalis pedis artery enters the sole of the foot.

The **Interossei plantares** (fig. 623), three in number, lie beneath rather than between the metatarsal bones, and each is connected with but one metatarsal bone. They arise from the bases and medial sides of the bodies of the third, fourth, and fifth metatarsal bones, and are inserted into the medial sides of the bases of the first phalanges of the same toes, and into the aponeuroses of the tendons of the Extensor digitorum longus.

Nerve-supply.—The Interossei dorsales et plantares are supplied by the first and second sacral nerves, through the lateral plantar nerve. The first Interosseous dorsalis frequently receives an extra filament from the medial branch of the deep peronæal nerve on the dorsum of the foot, and the second Interosseous dorsalis a twig from the lateral branch of the same nerve.

Fig. 622.—The Interossei dorsales of the left foot. Dorsal aspect.

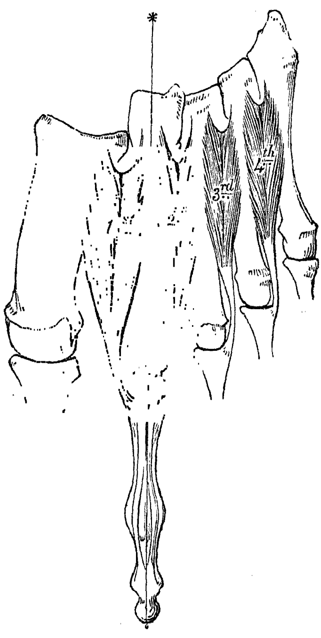
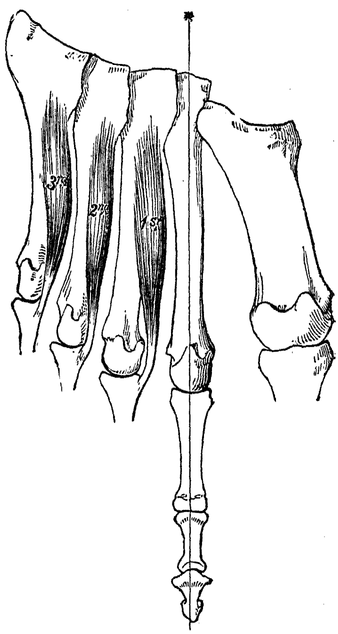


Fig. 623.—The Interossei plantares of the left foot. Plantar aspect.



Actions.—The Interossei dorsales are abductors from an imaginary line passing through the axis of the second toe, so that the first muscle draws the second toe medialwards, the second muscle draws the same toe lateralwards, and the third and fourth draw the third and fourth toes lateralwards. They assist in flexing the first and extending the second and third phalanges. The Interossei plantares adduct the third, fourth, and fifth toes towards the imaginary line passing through the second toe, and, by means of their insertions into the aponeuroses of the Extensor tendons, assist in flexing the proximal phalanges and extending the middle and terminal phalanges.

Applied Anatomy.—The student should now consider the effects produced by the action of the various muscles in fractures of the bones of the lower extremity. The more common forms of fracture are selected for illustration and description.

In fracture of the *neck of the femur inside the articular capsule* (fig. 624), the characteristic signs are slight shortening of the limb, and eversion of the foot, neither of which may appear until some time after the injury. The eversion is caused by the weight of the limb rotating it outwards. The shortening is produced by the contraction of all the muscles about the joint. The fragment which carries the head of the femur receives its nutrition through the vessels in the ligamentum teres.

In fracture of the *femur just below the trochanters* (fig. 625), the upper fragment is tilted forwards almost at right angles with the pelvis, by the Psoas major and Iliacus; and, at the same time, everted and abducted by the external rotator muscles and Glutæi, causing a marked prominence at the upper and lateral side of the thigh, and much pain from the

bruising and laceration of the muscles. The limb is shortened, because the lower fragment is drawn upwards by the Rectus femoris in front, and the Biceps femoris, Semimembranosus, and Semitendinosus behind ; it is, at the same time, everted.

FIG. 624.—A fracture of the neck of the femur within the articular capsule.

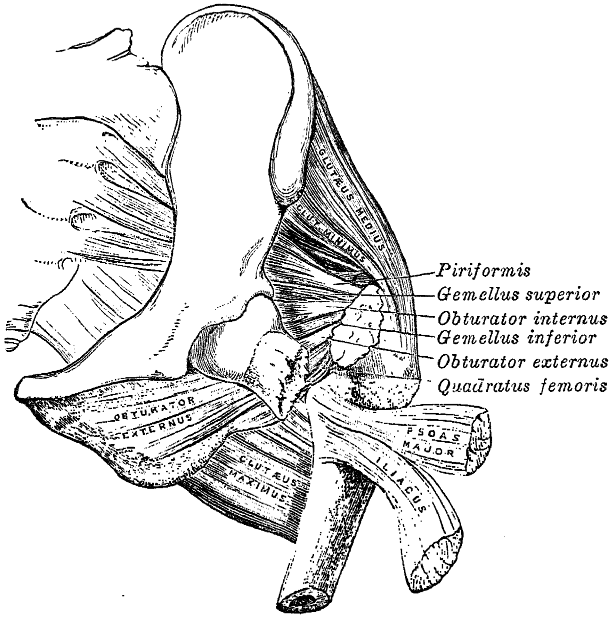
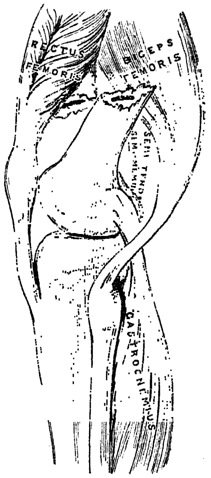


FIG. 625.—A fracture of the femur below the trochanters.

FIG. 626.—A fracture of the femur above the condyles.



Oblique fracture of the femur *immediately above the condyles* (fig. 626) is a formidable injury, and attended with considerable displacement. On examination of the limb, the lower fragment may be felt deep in the popliteal fossa, being drawn backwards by the Gastrocnemius, and upwards by the hamstrings and Rectus femoris, and in this position the fragment may compress the popliteal artery and so cause gangrene. The pointed end of the upper fragment is drawn medialwards by the Pectineus and Adductores, and tilted forwards by the Psoas major and Iliacus, piercing the Rectus, and occasionally the integument.

In transverse fracture of the *patella* (fig. 627) the fragments are separated by the action of the Quadriceps femoris and by the effusion which takes place into the joint; the extent of separation of the two fragments depending upon the degree of laceration of the ligamentous structures around the bone.

Fig. 627.—A fracture of the patella.

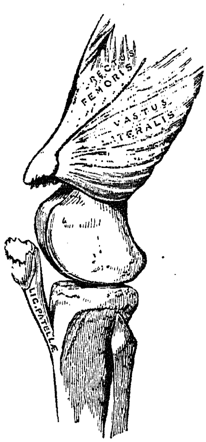
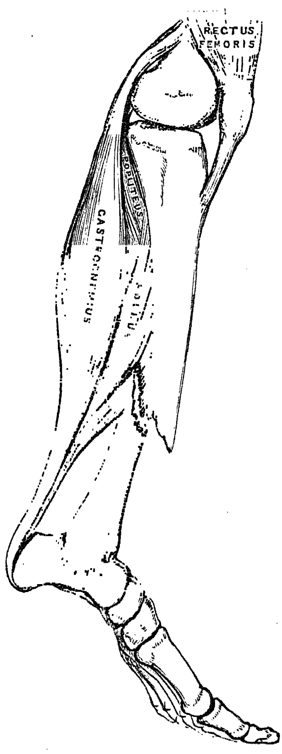


Fig. 628.—An oblique fracture of the body of the tibia.



Oblique fracture of the *body of the tibia* (fig. 628). If the fracture takes place obliquely from above, downwards and forwards, the fragments ride over one another, the lower fragment being drawn backwards and upwards by the powerful action of the muscles of the calf; the pointed extremity of the upper fragment projects forwards immediately beneath the integument, often protruding through it, and rendering the fracture compound. If the direction of the fracture is the reverse of that shown in the figure, the pointed extremity of the lower fragment projects forwards, rising up on the lower end of the upper one.

Fracture of the *fibula with dislocation of the foot lateralwards*, commonly known as 'Pott's fracture,' is one of the most frequent injuries in the region of the ankle-joint. The fibula is fractured about 7 or 8 cm. above the ankle; in addition to this the medial malleolus is broken off, or the deltoid ligament torn through, and the talus displaced from the corresponding surface of the tibia. The foot is markedly everted, and the sharp edge of the upper end of the fractured malleolus presses strongly against the skin; at the same time, the heel is drawn up by the muscles of the calf.

ANGIOLOGY

THE vascular system is divided for descriptive purposes into (*a*) the *blood-vascular system*, comprising the heart and blood-vessels through which the blood circulates; * and (*b*) the *lymph-vascular system*, consisting of lymph-glands and lymphatic vessels, through which a colourless fluid, the lymph, circulates. The two systems communicate with each other and are intimately associated developmentally.

The heart, the central organ of the blood-vascular system, is situated within the thorax. It is a muscular bag, by the contraction of which the blood is pumped to all parts of the body through a complicated series of tubes, termed *arteries*. The arteries undergo enormous ramification in their course throughout the body, and end in minute vessels, called *arterioles*, which open into a close-meshed network of microscopic vessels, termed *capillaries*. After the blood has passed through the capillaries it is collected into a series of minute vessels called *venules*, and which join with one another to form *veins*: the veins unite with one another, and ultimately two large venous trunks, named the superior and inferior venæ cavæ, are formed which return the blood to the heart. While the blood is passing through the capillaries a transudation of certain of its fluid elements takes place into the tissue-spaces; this fluid is collected by the lymphatic vessels, and returned to the large veins at the root of the neck. The passage of the blood through the heart and blood-vessels is termed the *circulation* of the blood, of which the following is an outline.

The heart is divided into right and left halves, and each half consists of two cavities, an atrium and a ventricle, which communicate freely with one another; the atria are receiving chambers and the ventricles distributing ones. The right atrium and ventricle form the right half, and the left atrium and ventricle the left half of the heart; the right half contains venous or impure blood; the left, arterial or pure blood. From the cavity of the left ventricle the arterial or pure blood is carried into a large artery, the aorta, through the numerous branches of which it is distributed to all parts of the body, with the exception of the lungs. As the blood traverses the capillaries of the body it gives up to the tissues the materials necessary for their growth and nourishment, and receives from the tissues the waste products resulting from their metabolism. In doing so it is changed from arterial into venous blood, and the latter is returned by the veins to the right atrium of the heart. From this cavity the venous blood passes into the right ventricle, and from it is conveyed through the pulmonary arteries to the lungs, where it becomes arterialised, and is carried thence to the left atrium by the pulmonary veins. From the left atrium it passes into the left ventricle, from which the cycle once more begins.

The course of the blood from the left ventricle through the body generally to the right side of the heart constitutes the greater or *systemic* circulation, while its passage from the right ventricle through the lungs to the left side of the heart is termed the lesser or *pulmonary* circulation.

It is necessary, however, to state that the blood which circulates through the spleen, pancreas, stomach, small intestine, and the greater part of the large intestine is not returned directly from these organs to the heart, but is conveyed by the *portal vein* to the liver. In the liver this vein divides like an artery, and ultimately ends in capillary-like vessels (sinusoids), from which

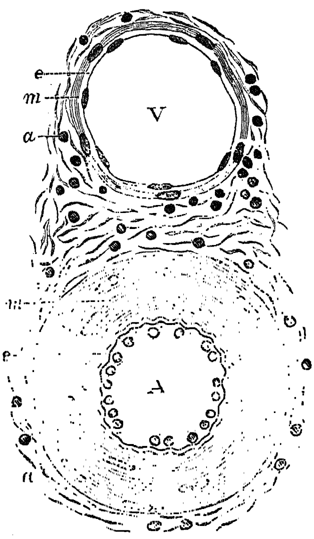
* The blood is described on pp. 26 to 28.

the rootlets of the *hepatic veins* arise; the hepatic veins carry the blood into the inferior vena cava which conveys it to the right atrium. From this it will be understood that the blood supplied to the above-named viscera passes through two sets of minute vessels before reaching the inferior vena cava: (1) the capillaries in the spleen, pancreas, stomach, &c., draining into the portal vein, and (2) the sinusoids in the liver, draining into the hepatic veins.

The **structure of the arteries** (figs. 629, 630).—The wall of an artery consists of three coats, an internal or *tunica intima*, a middle or *tunica media*, and an external or *tunica adventitia*. The external coat is tougher than the other two, which are ruptured when a ligature is tied round the vessel, and, in virtue of their elasticity, become retracted from the site of the ligature.

The *tunica intima* consists of (*a*) an internal layer of flattened cells, (*b*) beneath these, a small quantity of loose connective tissue, and (*c*) an elastic lamina. The flattened or endothelial cells are fusiform in shape with the long axis of each in the long axis of the blood-vessel. Each cell possesses a nucleus, and is attached to adjacent cells by cement-substance which reduces silver nitrate. The connective tissue layer is very thin, and contains branched cells, and, in the larger arteries, fine elastic fibres. The elastic lamina is built up of longitudinally arranged elastic fibres fused together, and is usually fenestrated, having round or oval apertures at irregular intervals. In a transverse section of an artery it appears as a characteristic wavy line, owing to the contracted condition of the empty vessel.

Fig. 629.—A transverse section through a small artery and vein of the mucous membrane of the epiglottis of a child. × 350. (Klein and Noble Smith.)



A. Artery; *a*, tunica adventitia; *e*, endothelium resting on the elastic lamina; *m*, tunica media.
V. Vein; *a*, tunica adventitia; *m*, tunica media; *e*, endothelium.

The *tunica media*, in the smaller and medium-sized arteries, consists principally of smooth muscular fibres arranged circularly round the vessel; the fibres have well-marked, rod-shaped nuclei. In the smallest arteries the middle coat is entirely composed of smooth muscular fibres (fig. 630). In medium-sized arteries (fig. 631) there are in addition elastic fibres and fine elastic membranes lying between the layers of muscular fibres. In the larger arteries, as the iliac and carotid, the proportion of elastic tissue is greatly increased, and in the aorta relatively thick elastic laminæ form the greater part of the thickness of the middle coat.

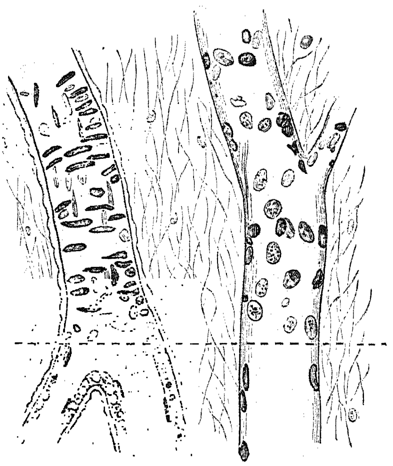
The *tunica adventitia* consists mainly of fine and closely felted bundles of white connective tissue; in all but the smallest arteries it contains some elastic fibres. The elastic tissue is most abundant next the tunica media, and it is sometimes described as forming here, between the adventitia and media, a special layer, the *tunica elastica externa*; this layer is most marked in arteries of medium size. In the largest vessels the external coat is relatively thin. From the medium-sized to the smaller arteries it diminishes gradually in thickness; in the smallest arteries the elastic fibres are wanting, and the connective tissue, of which the coat is composed, becomes more homogeneous the nearer it approaches the capillaries, and is gradually reduced to a thin membranous envelope, which finally disappears.

Some arteries have extremely thin walls in proportion to their size; this is especially the case in those situated within the cranium and vertebral canal, where the external and middle coats of the arteries are reduced in thickness.

The arteries, in their distribution throughout the body, are enclosed in thin fibro-areolar *sheaths*. An artery is loosely connected with its sheath by delicate areolar tissue; and the sheath usually encloses the accompanying veins, and sometimes a nerve. Some arteries, as those in the cranium, are devoid of sheaths.

The larger arteries are supplied with blood-vessels. These nutrient vessels, called the *vasa vasorum*, arise from branches of the artery itself, or of a neighbouring vessel, at some considerable distance from the points at which they are distributed; they ramify in the loose areolar tissue connecting the artery with its sheath, and are distributed to the external coat; in man they do not penetrate the other coats; but in some of the larger mammals a few vessels have been traced into the middle coat. Minute veins return the blood from these vessels; they empty themselves into the vein or veins accompanying the artery. Lymphatic vessels are also present in the outer coat.

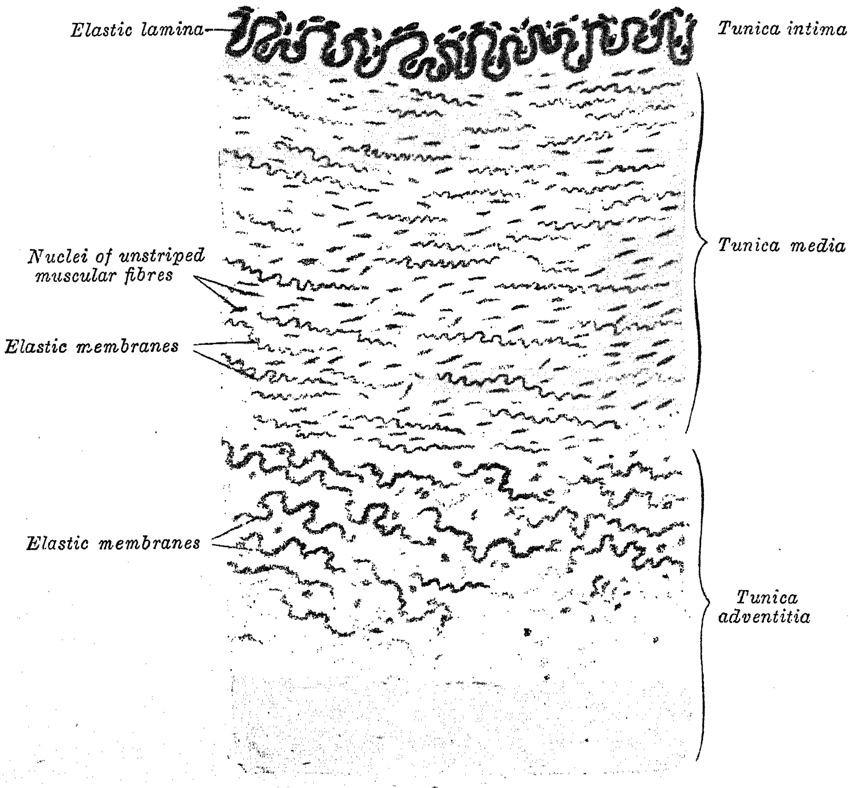
Fig. 630.—A small artery and vein, from the pia mater of a sheep. × 250.



Surface view above the interrupted line; optical section below. Artery in red; vein in blue.

Arteries are also supplied with nerves, which form intricate plexuses upon the surfaces of the larger trunks, and run along the smaller arteries as single filaments, or bundles of filaments. Most of the nerve-fibres are non-medullated, and are derived from the sympathetic system, but some are medullated. The non-medullated fibres are mostly efferent, and end in the middle coat. The medullated fibres are believed to be afferent and are distributed to the outer and inner coats. Pacinian corpuscles are occasionally found in the outer coat of the aorta.

Fig. 631.—A transverse section through the wall of a femoral artery of a dog. × 250.



The **capillaries.**—The arterioles (excepting those of the cavernous structure of the sexual organs, of the splenic pulp, and of the placenta), subdivide into minute

vessels named *capillaries* which are interposed between the arterioles and the venules, and constitute a network, the branches of which maintain the same diameter throughout.

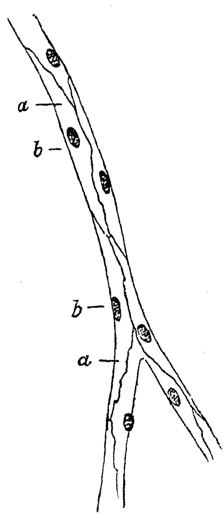
The *diameters* of the capillaries vary in the different tissues of the body, the usual size being about 8 μ when the blood is circulating. The smallest are found in the brain and in the mucous membrane of the intestines; the largest in the skin, and in the marrow of bone, where they may have a diameter of 20 μ.

The *form* of the capillary network varies in the different tissues, the meshes being generally round or elongated. Round or angular meshes are most common, and prevail where there is a dense network, as in the lungs, in most glands and mucous membranes, and in the cutis. Elongated meshes occur in muscles and nerves, the long axis of the mesh running parallel with that of the muscle or nerve. Sometimes the capillaries have a looped arrangement, as in the papillae of the tongue and skin.

The number of the capillaries and the size of the meshes determine the degree of vascularity of a part; the smallest meshes are found in the lungs and in the chorioid coat of the eye. As a general rule, the more active the function of the organ, the closer is its capillary net and the larger its supply of blood. Few blood-vessels are present in tendons, because in the latter little organic change occurs after their formation.

The structure of the capillaries.—The wall of a capillary consists of flattened cells joined edge to edge by cement-substance, and continuous with the endothelial cells which line the arteries and veins. When stained with nitrate of silver the material which unites the edges of the epithelial cells is displayed, thus showing the outlines of the cells (fig. 632). These cells are of large size and of an irregular polygonal or lanceolate shape, each containing an oval nucleus which may be displayed by carmine or hæmatoxylin. Between their edges, at various points of their meeting, roundish dark spots are sometimes seen, which have been described as stomata, though they are closed by intercellular substance. By some they are believed to be the situations through which the colourless corpuscles of the blood, when migrating from the blood-vessels, emerge; but this view is not universally accepted.

FIG. 632.—Capillaries from the mesentery of a guinea-pig, after treatment with a solution of nitrate of silver.



a. Cells. *b*. Their nuclei.

In developing capillaries, and in the capillaries of the glomeruli of the kidneys, the intestinal villi, and the chorioid coat of the eye, intercellular cement cannot be demonstrated, and the cells are believed to form a syncytium.

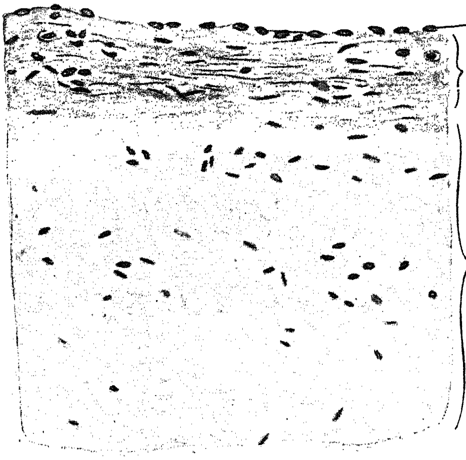
In many situations a delicate sheath or envelope of branched nucleated connective tissue cells is found around the simple capillary tubes, particularly the larger ones; and in other places, especially in the glands, the capillaries are invested with retiform connective tissue.

The sinusoids.—In the heart, the liver, the suprarenal and parathyreoid glands, the glomera carotica and glomus coccygeum, the smallest blood-vessels differ from true capillaries. They are wider, with an irregular lumen, and have no connective tissue covering, their endothelial cells being in direct contact with the cells of the organ. Moreover, their walls are often incomplete. These vessels have been called *sinusoids* by Minot. They are formed by columns of cells or trabeculæ pushing their way into a large blood-vessel or blood-space and carrying its endothelium before them; at the same time the wall of the vessel or space grows out between the columns of cells.

The structure of the veins.—The walls of the veins, like those of the arteries, are composed of three coats—internal, middle, and external; and these are, with the necessary modifications, analogous to the coats of the arteries; the internal being the endothelial, the middle the muscular, and the external the connective tissue or areolar (fig. 629). The main difference between the veins and the arteries is in the comparative weakness of the middle coat in the former.

In the smallest veins the three coats are hardly to be distinguished (fig. 630). The endothelium is supported on a membrane separable into two layers, the outer of which is the thicker, and consists of a delicate, nucleated membrane (tunica adventitia), while the inner is composed of a network of longitudinal elastic fibres (tunica media). In the veins next above these in size (0·4 mm. in diameter), a connective tissue layer containing numerous smooth muscular fibres circularly disposed can be traced, forming the middle coat, while the elastic and connective tissue elements of the outer coat are more distinctly perceptible. In the middle-sized veins (fig. 633) the endothelium is of the same character as in the arteries, but its cells are shorter and broader. It is supported by a connective tissue layer, consisting of a delicate network of branched cells, and external to this is a layer of elastic fibres disposed in the form of a network in place of the definite fenestrated membrane seen in arteries. This constitutes the *tunica intima*. The *tunica media* is composed of a thick layer of connective tissue with elastic fibres, intermixed, in some veins, with a layer of smooth muscular fibres arranged circularly. The white fibres are in considerable excess, and the elastic fibres are in much smaller proportion in the veins than in the arteries. The *tunica adventitia* consists, as in the arteries, of areolar tissue with longitudinal elastic fibres. In the largest veins it is from two to five times thicker than the tunica media, and contains a large number of longitudinal muscular fibres. These are most distinct in the inferior vena cava, especially at the termination of this vein in the heart, in the trunks of the hepatic veins, in all the large trunks of the portal vein, and in the external iliac, renal, and azygos veins. In the inferior vena cava, renal and portal veins they extend through the whole thickness of the outer coat, but in the other veins mentioned a layer of connective and elastic tissue is found external to the muscular fibres. The large veins which open into the heart are covered for a short distance with a layer of striped muscular tissue continued on to them from the heart. Muscular tissue is wanting—(1) in the veins of the maternal part of the placenta; (2) in the venous sinuses of the dura mater and the veins of the pia mater; (3) in the veins of the retina; (4) in the veins of the spongy substance of bones; (5) in the venous spaces of the corpora cavernosa. The veins of the above-mentioned parts consist of an endothelial lining supported on one or more layers of areolar tissue.

FIG. 633.—A transverse section through the wall of a femoral vein of a dog. ×250. The elastic tissue is not differentiated in this preparation.



Most veins are provided with *valves* which serve to prevent the reflux of the blood. Each valve is formed by a reduplication of the inner coat, strengthened by connective tissue and elastic fibres, and is covered on both surfaces by endothelium, the arrangement of which differs on the two surfaces. On the surface of the valve next the wall of the vein, the cells are arranged transversely; while on the other surface, over which the current of blood flows, the cells are arranged longitudinally in the direction of the current. Most commonly two such valves are found placed opposite one another, more especially in the smaller veins or in the larger trunks at the point where they are joined by smaller branches; occasionally there are three and sometimes only one. The valves are semilunar. They are attached by their convex edges to the wall of the vein; the concave margins are free, directed in the course of the venous current, and lie in close apposition with the wall of the vein as long as the current of blood takes its natural course; if, however, any regurgitation takes place, the valves become distended, their opposed edges are brought into contact, and the current is interrupted. The wall of the vein on the cardiac side of the attachment of each valve is expanded

into a pouch or sinus, which gives to the vessel, when injected or distended with blood, a knotted appearance. The valves are very numerous in the veins of the extremities, especially in the veins of the lower extremities, these vessels having to conduct the blood against the force of gravity. They are absent in the very small veins, i.e. those less than 2 mm. in diameter, also in the venæ cavæ, hepatic, renal, uterine, and ovarian veins. The cerebral and spinal veins, the veins of the cancellated tissue of bone, the pulmonary veins, and the umbilical vein and its branches, are also destitute of valves. A few valves are found in each testicular vein, and one also at its point of junction with the renal vein or inferior vena cava respectively. A few valves are occasionally found in the azygos and intercostal veins. Valves are present in the tributaries of the portal vein in the fœtus and for a short time after birth; as a rule they soon atrophy and disappear, but sometimes they persist in a degenerate form.

The larger veins, like the arteries, are supplied with nutrient vessels, *vasa vasorum*. Nerves also are distributed to the veins in the same manner as to the arteries, but in much less abundance.

The Thoracic Cavity

The heart and lungs are situated within the thorax, the walls of which afford them protection. The heart lies between the two lungs, and is enclosed within a fibrous bag, the *pericardium*, while each lung is covered with a serous membrane, the *pleura*; the space between the pleural membranes is named the *mediastinal cavity*. The skeleton of the thorax, and the shape and boundaries of the cavity, have already been described (p. 193).

The **cavity of the thorax**.—The capacity of the thoracic cavity does not correspond with its apparent size externally, because (1) the lower part of the space enclosed by the ribs is occupied by some of the abdominal viscera; and (2) the thoracic cavity extends for a short distance into the neck above the anterior parts of the first ribs. During life the size of the thoracic cavity is constantly varying with the movements of the ribs and Diaphragm, and with the degree of distension of the abdominal viscera.

The **upper opening of the thorax**.—The parts which pass through the upper opening of the thorax are, from before backwards in or near the middle line, the Sternohyoideus and Sternothyreoideus muscles, the remains of the thymus, the inferior thyreoid veins, the trachea, œsophagus, thoracic duct and the Longus colli muscles; laterally the innominate veins, the innominate artery, the left common carotid and left subclavian arteries, the internal mammary arteries and the costocervical trunks, the vagus, cardiac, phrenic, and sympathetic nerves, the greater parts of the anterior divisions of the first thoracic nerves, and the left recurrent nerve. The apex of each lung, covered by the pleura, also projects through this aperture, a little above the level of the sternal end of the first rib.

The **lower opening of the thorax** is wider transversely than from before backwards. It slopes obliquely downwards and backwards, so that the thoracic cavity is much deeper behind than in front. The Diaphragm (p. 464) closes the opening and forms the floor of the thorax. The floor is flatter at the centre than at the sides, and higher on the right side than on the left; in the dead body the right side reaches the level of the upper border of the fifth costal cartilage, while the left extends only to the corresponding part of the sixth costal cartilage. From the highest point on either side the floor slopes suddenly downwards to the costal and vertebral attachments of the Diaphragm; this slope is more marked behind than in front, so that only a narrow space is left between the Diaphragm and the posterior wall of the thorax.

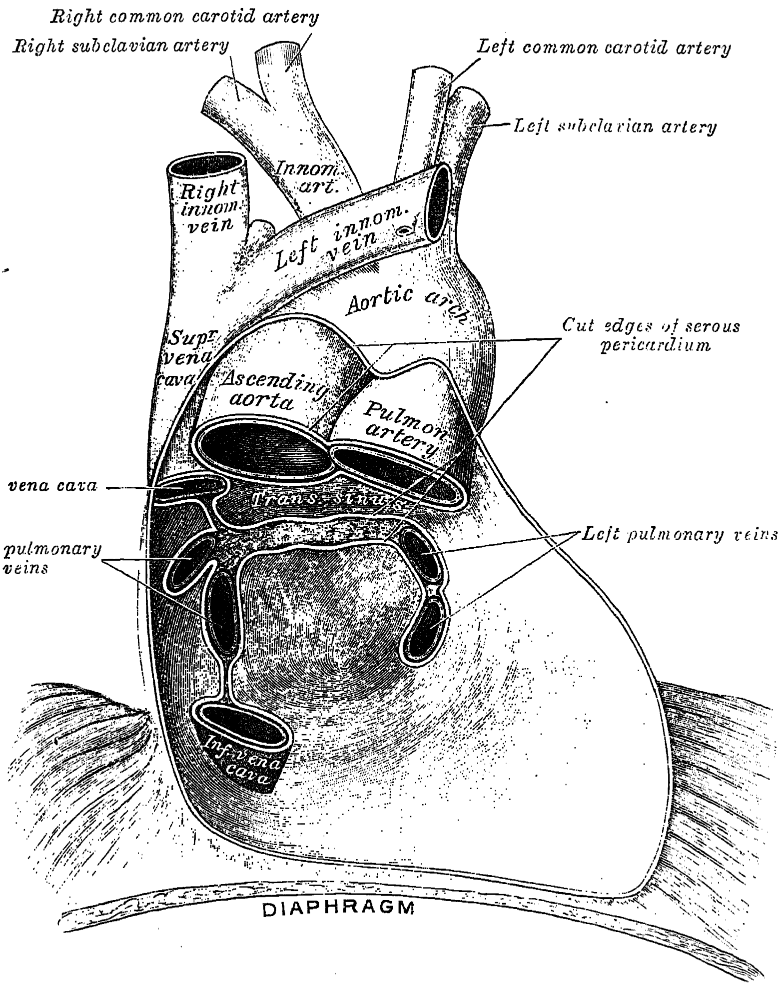
The Pericardium

The **pericardium** (fig. 634) is a conical fibroserous sac which contains the heart and the roots of the great vessels. It is placed in the mediastinal cavity, behind the sternum and the cartilages of the third, fourth, fifth, sixth, and

seventh ribs of the left side, and in front of the thoracic vertebræ, from the fifth to the eighth inclusive.

In *front*, it is separated from the anterior wall of the thorax, in the greater part of its extent, by the lungs and pleuræ; but a small area, usually corresponding with the left half of the lower part of the body of the sternum, and the sternal ends of the cartilages of the fourth and fifth ribs of the left side, is in direct relationship with the chest-wall. Until puberty or adolescence

FIG. 634.—The posterior wall of the pericardial sac, showing the lines of reflection of the serous pericardium on to the great vessels.



the lower end of the thymus is in contact with the front of the upper part of the pericardium. *Behind*, the pericardium rests upon the bronchi, the œsophagus, the œsophageal plexus of nerves, the descending thoracic aorta, and the posterior part of the mediastinal surface of each lung. *Laterally*, it is covered by the pleuræ, and is in relation with the mediastinal surfaces of the lungs; the phrenic nerve, with its accompanying vessels, descends between the pericardium and the mediastinal pleura on either side.

The **structure of the pericardium.**—Although the pericardium is usually described as a single sac, an examination of its structure shows that it consists essentially of two sacs intimately connected with one another, but totally different in structure. The outer sac, known as the *fibrous pericardium*, consists of fibrous tissue. The inner sac, or *serous pericardium*, is a delicate membrane

of the lateral lip of the linea aspera: this aponeurosis covers the upper three-fourths of the muscle, and from its deep surface many fibres take origin. A few additional fibres arise from the tendon of the Glutæus maximus, and from the lateral intermuscular septum between the Vastus lateralis and short head of the Biceps femoris. The fibres form a large fleshy mass, which is attached to a strong aponeurosis, placed on the deep surface of the lower part of the muscle: this aponeurosis contracts into a flat tendon which is inserted into the lateral border of the patella, blending with the Quadriceps femoris tendon, and giving an expansion to the capsule of the knee-joint.

The Vastus medialis and Vastus intermedius appear to be inseparably united, but when the Rectus femoris has been reflected a narrow interval will be observed extending upwards from the medial border of the patella between the two muscles, and the separation may be carried to the lower part of the intertrochanteric line, where, however, the two muscles are frequently continuous.

The **Vastus medialis** arises from the lower one-half of the intertrochanteric line, the medial lip of the linea aspera, the upper part of the medial supracondylar ridge, the tendons of the Adductor longus and Adductor magnus, and the medial intermuscular septum. Its fibres are directed downwards and forwards, and are chiefly attached to an aponeurosis which lies on the deep surface of the muscle and is inserted into the medial border of the patella and the Quadriceps femoris tendon, an expansion being sent to the capsule of the knee-joint.

The **Vastus intermedius** (Crureus) arises from the front and lateral surfaces of the upper two-thirds of the body of the femur, and from the lower part of the lateral intermuscular septum. Its fibres end in a superficial aponeurosis, which forms the deep part of the Quadriceps femoris tendon.

The *tendons* of the different portions of the Quadriceps unite at the lower part of the thigh, to form a single strong tendon which is inserted into the base of the patella, some fibres passing over it to blend with the ligamentum patellæ. More properly, the patella may be regarded as a sesamoid bone developed in the tendon of the Quadriceps; and the ligamentum patellæ, which is continued from the apex of the patella to the tuberosity of the tibia, as the proper tendon of insertion of the muscle, the medial and lateral patellar retinacula (p. 410) being expansions from its borders. A bursa, which usually communicates with the cavity of the knee-joint, is situated between the femur and the portion of the Quadriceps tendon above the patella; another is interposed between the ligamentum patellæ and the upper part of the front of the tibia (fig. 522).

The **Articularis genus** (Subcrureus) is a small muscle, usually distinct from the Vastus intermedius, but occasionally blended with it; it consists of several muscular bundles which arise from the anterior surface of the lower part of the body of the femur, and are inserted into the upper part of the synovial stratum of the articular capsule of the knee-joint.

Nerve-supply.—The Quadriceps femoris and the Articularis genus are supplied by the second, third, and fourth lumbar nerves, through the femoral nerve.

Actions.—The Quadriceps femoris extends the leg upon the thigh. The Rectus femoris assists the Psoas major and Iliacus in supporting the pelvis and trunk upon the femur; it also assists in flexing the thigh on the pelvis, or if the thigh be fixed it will flex the pelvis. The Vastus medialis draws the patella medialwards as well as upwards. The Articularis genus pulls upwards the synovial stratum of the articular capsule of the knee-joint during extension of the leg.

Applied Anatomy.—A few fibres of the Rectus femoris are occasionally ruptured from severe strain. This accident is especially liable to occur during the games of football and cricket, and is sometimes known as 'cricket thigh.' The patient experiences a sudden pain in the part, as if he had been struck, and the Rectus stands out and is felt to be tense and rigid. The accident is often followed by considerable swelling from inflammatory effusion. The Quadriceps femoris may be torn away from its insertion into the patella. This accident is caused in the same manner as fracture of the patella by muscular action, viz. by a violent muscular effort to prevent falling while the knee is in a position of semiflexion. A distinct gap can be felt above the patella, and, owing to the retraction of the muscular fibres, union may fail to take place. The ligamentum patellæ may be ruptured about 2·5 cm. above the tibia; or the tuberosity of the tibia may be torn from the bone; the last condition is more likely to happen before the ossification of the tuberosity is completed, i.e. before the age of twenty years.

the level of the ninth or tenth rib, and extending laterally as far as the inferior angle of the scapula; the underlying lung-tissue gives the physical signs of compression or collapse.

Paracentesis of the pericardium and withdrawal of the fluid within it is sometimes necessary to relieve embarrassment of the heart's action. The puncture may be made in the fifth or sixth left intercostal space near the sternum, with care to avoid wounding the internal mammary artery that usually runs 1·25 cm. lateral to the sternal edge. Alternatively the exploring needle may be entered at the left costoxiphoid angle, and passed upwards and backwards into the pericardial sac. Curschmann recommends paracentesis in or lateral to the left mammary line in the fifth or sixth left interspace, in view of the fact that the fluid tends to collect on either side of and below the heart rather than in front of it.

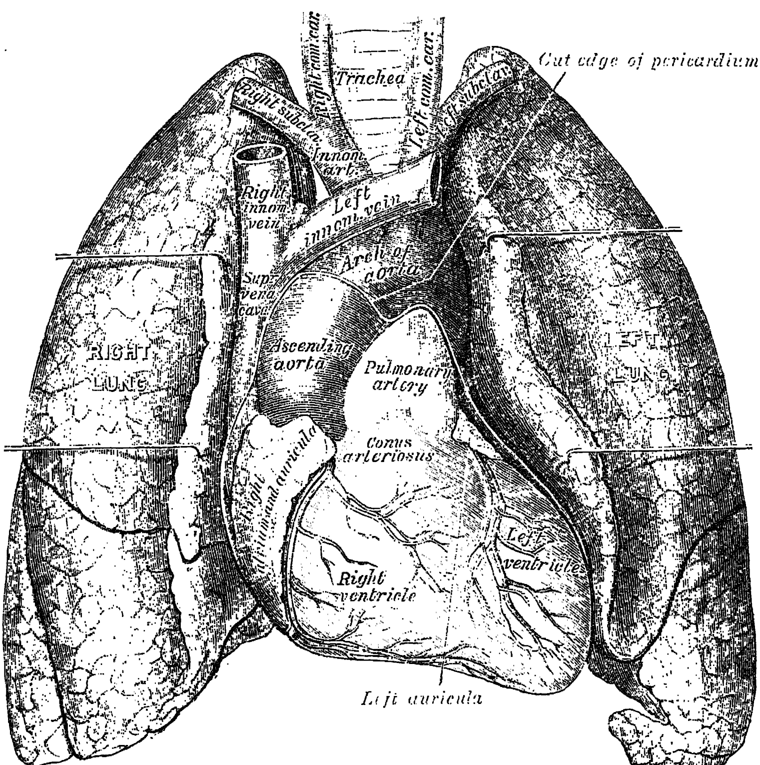
Periocardiotomy is required when the effusion is of a purulent nature. In this operation a portion of the fifth or sixth costal cartilage is excised. An incision is made along the left border of the sternum from the upper border of the fourth cartilage to the seventh. The fifth costal cartilage is now separated from the sternum and raised, the tissues beneath it being peeled off, so as to avoid wounding the internal mammary artery or the pleura. The fibres of the Transversus thoracis are then separated close to the sternum, and the pericardium felt for and opened, the finger guarding the pleura and left internal mammary artery.

Cardiolysis, or the operation of opening the pericardial sac and dividing adhesions between its visceral and parietal layers, is one that appears to have much to recommend it on clinical grounds. In practice, however, it has rarely proved satisfactory, owing to the great toughness and extent of the adhesions when they are present, and the free hæmorrhage that occurs when they are divided.

The Heart (Cor)

The **heart** is a muscular bag of a somewhat conical form; it lies between the lungs in the middle mediastinal cavity (fig. 635), and is enclosed in the

Fig. 635.—The heart and lungs. Anterior aspect.



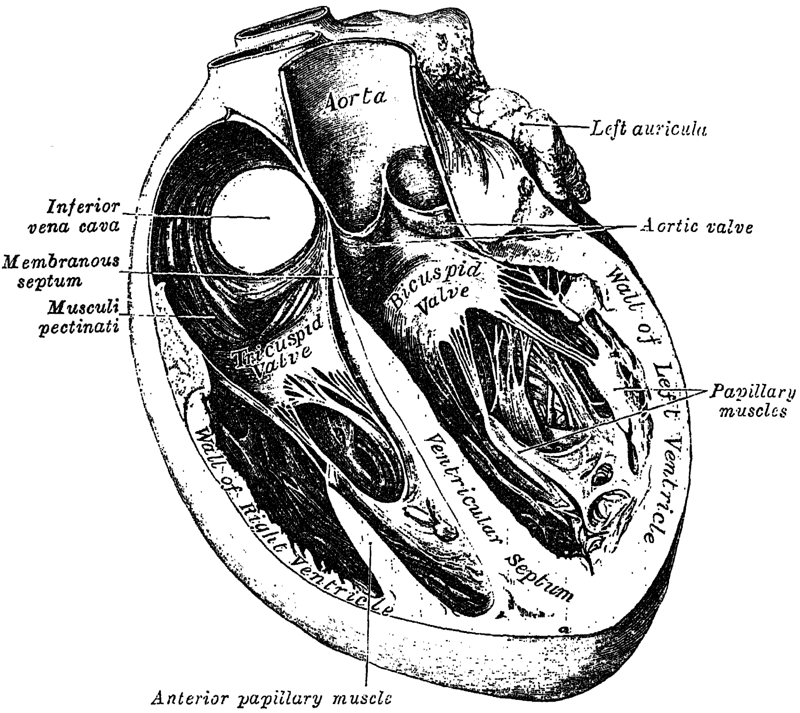
pericardium. It is placed obliquely in the chest behind the body of the sternum and adjoining parts of the rib cartilages, and projects farther into

the left than into the right half of the thoracic cavity, so that about one-third of it is situated on the right and two-thirds on the left of the median plane.

Size.—The heart of the adult measures about 12 cm. from base to apex, 8 to 9 cm. transversely at the broadest part, and 6 cm. anteroposteriorly. Its weight, in the male, varies from 280 to 340 grammes; in the female, from 230 to 280 grammes. It continues to increase in weight and size up to an advanced period of life, and this increase is more marked in men than in women.

Component parts.—As already stated (p. 567) the heart is divided into four chambers, viz. right and left atria, and right and left ventricles: the division is indicated on the surface of the heart by grooves or sulci. The atria are separated from the ventricles by the *coronary sulcus* (auriculoventricular groove); this sulcus contains the trunks of the coronary vessels of the heart,

FIG. 636.—A section through the heart, showing the ventricular septum.

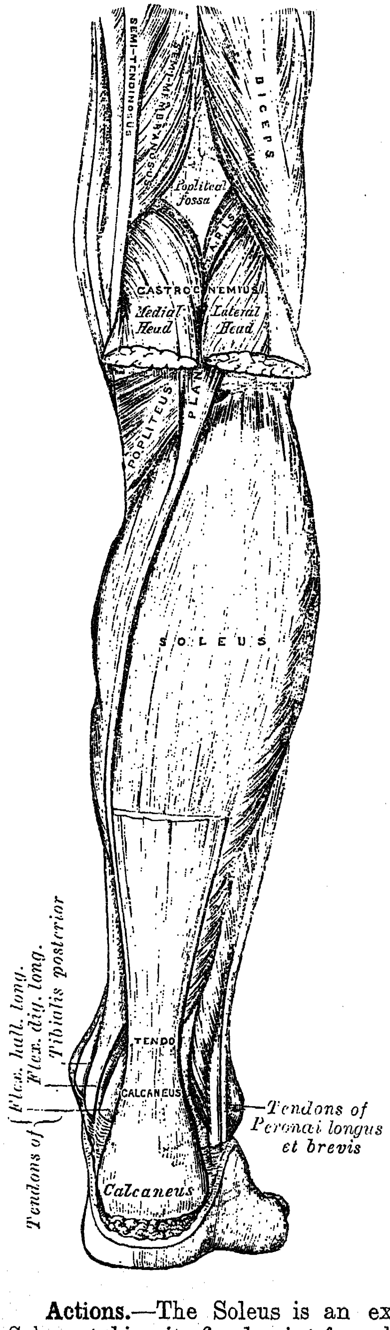


and is deficient in front, where it is crossed by the root of the pulmonary artery. The *interatrial groove*, separating the two atria, is scarcely marked on the posterior surface, while anteriorly it is hidden by the pulmonary artery and aorta. The ventricles are separated by two grooves, one of which, the *anterior longitudinal sulcus*, is situated on the sternocostal surface of the heart, near its left margin, the other, the *posterior longitudinal sulcus*, on the diaphragmatic surface near the right margin; these grooves extend from the base of the ventricular portion to a notch, the *incisura apicis cordis*, situated a little to the right of the apex of the heart.

The *base* (fig. 637) is somewhat quadrilateral in form; it looks upwards, backwards, and to the right, and is separated from the fifth, sixth, seventh, and eighth thoracic vertebræ by the pericardium, œsophagus, aorta, and thoracic duct. It is formed mainly by the left atrium, and, to a small extent, by the posterior part of the right atrium. It is in relation above with the bifurcation of the pulmonary artery, and is bounded below by the posterior part of the coronary sulcus, containing the coronary sinus. On the right it is limited by the sulcus terminalis of the right atrium, and on the left by the ligament of the left vena cava and the oblique vein of the left atrium. The four pulmonary veins, two on either side, open into the left atrium, whilst the superior vena

The fibres unite at an angle in the middle line of the muscle, in a tendinous raphe which expands into a broad aponeurosis on the anterior surface of the muscle, and into this the remaining fibres are inserted. The aponeurosis, gradually contracting, unites with the tendon of the Soleus, and forms with it the tendo calcaneus.

Fig. 611.—The right posterior crural muscles. Superficial group.



Relations.—The fascia cruris separates the *superficial surface* of the muscle from the small saphenous vein, and the peronæal anastomotic, medial sural cutaneous, and sural nerves; the common peronæal nerve crosses the lateral head of the muscle, lying partly under cover of Biceps femoris. The *deep surface* is in relation with the oblique popliteal ligament of the knee-joint, the Popliteus, Soleus, Plantaris, popliteal vessels, and tibial nerve. In front of the tendon of the medial head is a bursa, which, in some cases, communicates with the cavity of the knee-joint. The tendon of the lateral head sometimes contains a sesamoid fibrocartilage or bone, where it plays over the corresponding condyle; and one is occasionally found in the tendon of the medial head.

Nerve-supply.—The Gastrocnemius is supplied by the first and second sacral nerves, through the tibial nerve.

Actions.—Acting from above the Gastrocnemius extends the ankle-joint; acting from below it flexes the knee-joint.

The **Soleus** (figs. 609, 611) is a broad flat muscle situated immediately in front of the Gastrocnemius. It arises by tendinous fibres from the back of the head, and from the upper one-fourth of the posterior surface of the body, of the fibula; from the popliteal line and the middle one-third of the medial border of the tibia; and from a fibrous band which stretches between these origins and arches over the popliteal vessels and tibial nerve. The muscular fibres end in a flat tendon which covers the posterior surface of the muscle, and, gradually becoming thicker and narrower, joins with the tendon of the Gastrocnemius, and forms with it the tendo calcaneus.

Relations.—Its *superficial surface* is in relation with the Gastrocnemius and Plantaris; its *deep surface*, with the Flexor digitorum longus, Flexor hallucis longus, Tibialis posterior, and posterior tibial vessels and nerve, from all of which it is separated by the deep transverse fascia of the leg.

Nerve-supply.—The Soleus is supplied by the first and second sacral nerves through the tibial nerve.

Actions.—The Soleus is an extensor of the ankle-joint; in standing, the Soleus, taking its fixed point from below, steadies the leg on the foot.

The Gastrocnemius and Soleus together form a muscular mass which is occasionally described as the *Triceps suræ*; its tendon of insertion is the tendo calcaneus.

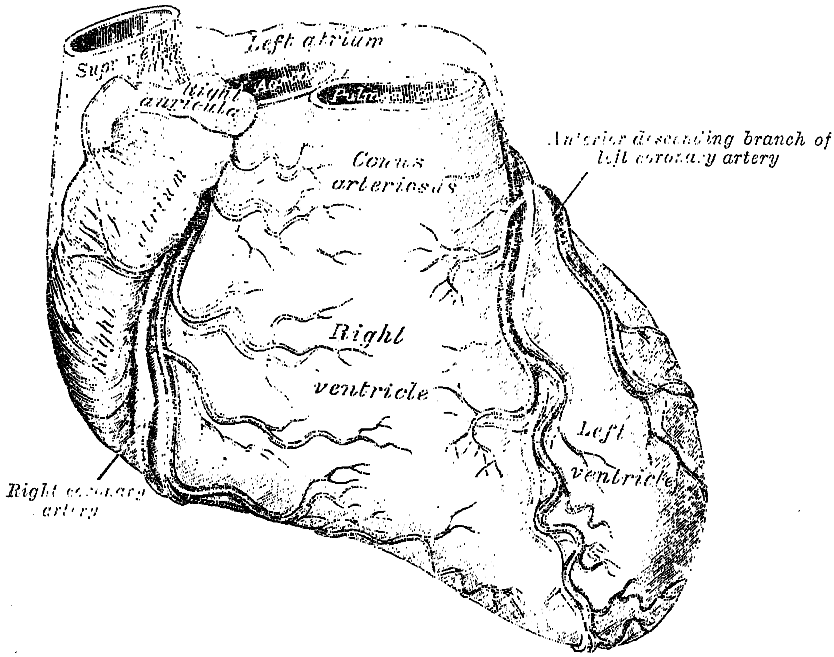
The **tendo calcaneus** (tendo Achillis) (fig. 611), the common tendon of the Gastrocnemius and Soleus, is the thickest and strongest in the body. It is

The *diaphragmatic surface* (fig. 637), directed downwards and slightly backwards, is formed by the ventricles (chiefly by the left ventricle), and rests upon the central tendon and a small part of the left muscular portion of the Diaphragm. It is separated from the base by the posterior part of the coronary sulcus, and is traversed obliquely by the posterior longitudinal sulcus.

The *right margin* of the heart, formed by the right atrium, is rounded and almost vertical; it is situated behind the third, fourth, and fifth right costal cartilages 1·25 cm. from the margin of the sternum.

The *inferior or acute margin*, formed almost entirely by the right ventricle, is nearly horizontal, and extends from the sternal end of the sixth right costal cartilage to the apex of the heart.

FIG. 638.—The sternocostal surface of the heart.



The *left or obtuse margin* is full and rounded; it is formed mainly by the left ventricle, but to a slight extent, above, by the left auricula. It extends from a point in the second left intercostal space, about 2 cm. from the sternal margin, obliquely downwards, with a convexity to the left, to the apex of the heart.

The **atrial septum.**—A partition, named the *atrial septum* (figs. 639, 642) intervenes between the right and left atria, and is so obliquely placed that the right atrium lies in front and to the right of the left atrium.

The **ventricular septum.**—The right ventricle is separated from the left by the *ventricular septum* (figs. 636, 642), which slopes obliquely from before backwards and towards the right, and is curved with the convexity towards the right ventricle: its margins correspond with the anterior and posterior longitudinal sulci on the surface of the heart. The greater portion of the septum is thick and muscular, and constitutes the *muscular ventricular septum*; but its upper and posterior part, which separates the aortic vestibule from the lower part of the right atrium and upper part of the right ventricle, is thin and fibrous, and is termed the *membranous ventricular septum.* A communication may exist between the ventricles at this part, owing to defective development of the membranous septum.

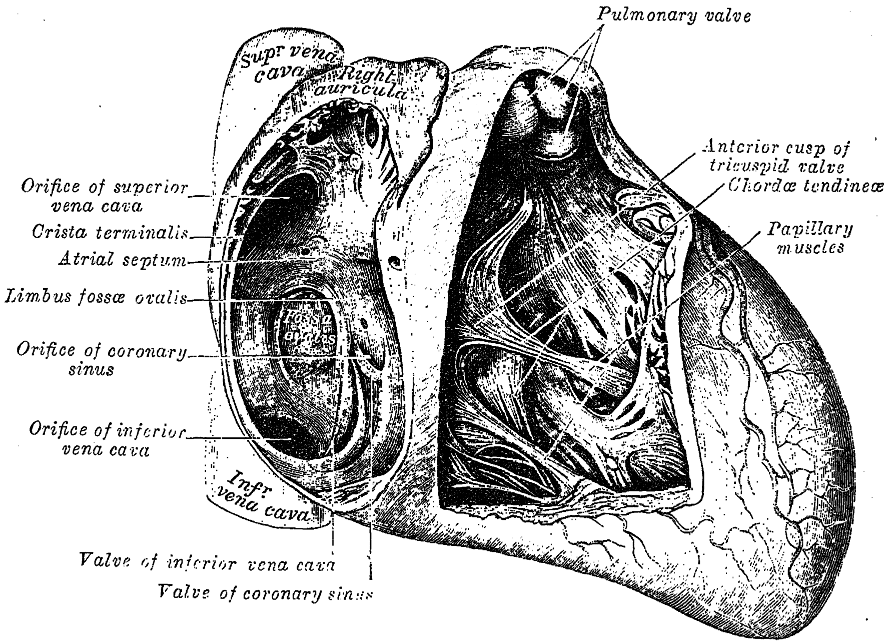
The **right atrium** (figs. 639, 642) consists of two parts: a principal cavity, or sinus venarum, situated posteriorly, and an anterior, smaller portion, the auricula.

The *sinus venarum* is the large quadrangular part placed between the two venæ cavæ. Its walls, which are extremely thin, are connected below with the right ventricle, and medially with the left atrium.

The *auricula* is a small, conical, muscular pouch, the margins of which present a dentated edge. It projects from the upper and front part of the sinus venarum forwards and towards the left side, overlapping the root of the aorta (fig. 638).

The separation of the auricula from the sinus venarum is indicated, on the outer surface of the atrium, by a groove, the *sulcus terminalis*, which extends from the front of the superior vena cava to the front of the inferior vena cava, and represents the line of union of the sinus venosus of the embryo with the

FIG. 639.—The interior of the right side of the heart.



primitive atrium. On the inner surface of the atrium the separation is marked by a vertical, smooth, muscular ridge, the *crista terminalis*. Behind the crista terminalis the internal surface of the atrium is smooth, while in front of it the muscular fibres of the wall are raised into parallel ridges resembling the teeth of a comb, and hence named the *musculi pectinati*.

The interior of the right atrium (fig. 639) presents the following parts for examination :

Orifices:
- Superior vena cava.
- Inferior vena cava.
- Coronary sinus.
- Foramina venarum minimarum.
- Right atrioventricular.

Valves:
- Valve of the inferior vena cava.
- Valve of the coronary sinus.

Fossa ovalis.
Limbus fossæ ovalis.
Intervenous tubercle.
Musculi pectinati.
Crista terminalis.

The *superior vena cava* (fig. 638) returns the blood from the upper half of the body, and opens into the upper and posterior part of the atrium. Its orifice is directed downwards and forwards, and has no valve.

The *inferior vena cava* (fig. 639), larger than the superior, returns the blood from the lower half of the body, and opens into the lowest part of the atrium near the atrial septum ; its orifice, directed upwards and backwards, is guarded by a rudimentary valve, the *valve of the inferior vena cava* (valve of Eustachius). The blood entering the atrium through the superior vena cava is directed downwards and forwards towards the atrioventricular orifice, whilst that entering through the inferior vena cava is directed upwards and backwards towards the atrial septum. This is the normal direction of the two currents in fœtal life.

The *coronary sinus* (fig. 637) returns the greater part of the blood from the substance of the heart. Its opening is placed between the orifice of the inferior vena cava and the atrioventricular opening, and is protected by a thin semicircular valve, the *valve of the coronary sinus* (valve of Thebesius).

The *foramina venarum minimarum* are the orifices of minute veins (*venæ cordis minimæ*), which return a small quantity of blood directly from the substance of the heart.

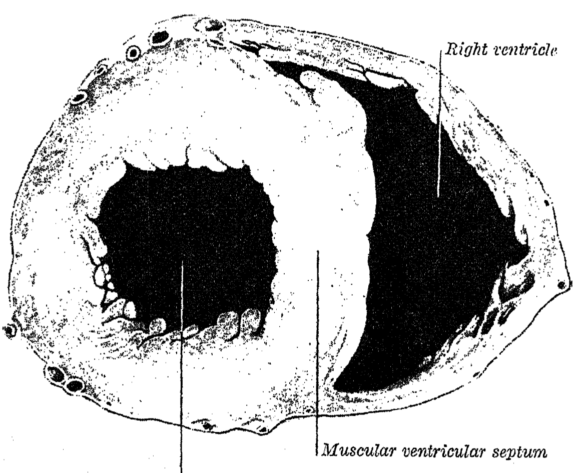
The *right atrioventricular orifice* is the large opening between the right atrium and ventricle ; it is described with the right ventricle (p. 583).

The *valve of the inferior vena cava* is situated in front of the orifice of the inferior vena cava. It is semilunar in form, its convex margin being attached to the anterior margin of the orifice ; its concave margin, which is free, ends in two cornua, of which the left is continuous with the anterior edge of the limbus fossæ ovalis, while the right is lost on the wall of the atrium. The valve is formed by a duplicature of the lining membrane of the atrium, containing a few muscular fibres. During fœtal life this valve is of large size, and serves to direct the blood from the inferior vena cava into the left atrium, through an opening, named the foramen ovale, in the atrial septum. It occasionally persists in the adult, and may assist in preventing the reflux of blood into the inferior vena cava; it may present a cribriform or filamentous appearance; sometimes it is absent.

The *valve of the coronary sinus* (fig. 639) is a semicircular fold of the lining membrane of the atrium, at the orifice of the coronary sinus. It prevents the regurgitation of blood into the sinus during the contraction of the atrium. This valve may be double or it may be cribriform.

The *fossa ovalis* (fig. 639) is an oval depression on the lower part of the septal wall of the atrium, above and to the left of the orifice of the inferior vena cava. It corresponds to the situation of the foramen ovale in the fœtus.

FIG. 640.—A transverse section through the ventricles of the heart.



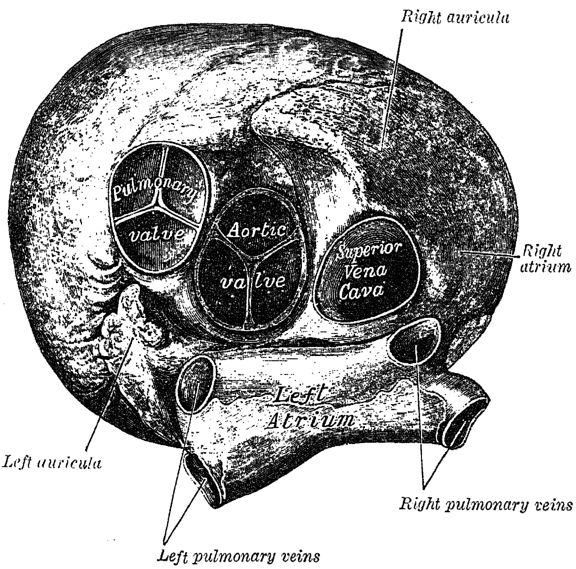
The *limbus fossæ ovalis* (annulus ovalis) (fig. 639) is the prominent margin of the fossa ovalis. It is most distinct above and at the sides of the fossa; below, it is deficient. A small slit-like valvular opening is occasionally found, at the upper margin of the fossa, leading upwards, beneath the limbus, into the left atrium; it is the remains of the foramen ovale between the two atria.

The *intervenous tubercle* (tubercle of Lower) is a small projection on the posterior wall of the atrium, above the fossa ovalis. It is distinct in the hearts of quadrupeds, but in man is scarcely visible. During fœtal life it may direct the blood from the superior vena cava towards the atrioventricular opening.

The *crista terminalis* and the *musculi pectinati* have been described (p. 581).

The **right ventricle** (figs. 639, 640, 642) extends from the right atrium to near the apex of the heart. Its anterosuperior surface is convex, and forms a large part of the sternocostal surface of the heart. Its inferior surface is flattened, rests upon the Diaphragm, and forms a small part of the diaphragmatic surface of the heart. Its posterior wall is formed by the ventricular septum, which bulges into the right ventricle, so that a transverse section of the cavity presents a crescentic outline (fig. 640). Its upper left angle forms a conical pouch, the *conus arteriosus*, from which the pulmonary artery arises. A tendinous band, the *tendon of the conus arteriosus*, connects the posterior surface of the conus arteriosus to the aorta; this tendon is continuous with the membranous ventricular septum. The wall of the right ventricle is thinner than that of the left, the proportion between them being as 1 to 3; it is thickest at the base, and gradually becomes thinner towards the apex of the ventricle. The cavity of the right ventricle is capable of holding about 85 c.c. of blood.

FIG. 641.—The heart. Superior aspect.



The interior of the right ventricle (fig. 639) presents the following parts for examination :

Orifices	Right atrioventricular. Pulmonary artery.	Valves	Tricuspid. Pulmonary.
	Trabeculæ carneæ.		Chordæ tendineæ.

The *right atrioventricular orifice* is the large oval aperture between the right atrium and ventricle. Situated at the base of the ventricle, it measures about 4 cm. in diameter and is encircled by a fibrous ring, covered with the lining membrane of the heart; it is considerably larger than the left atrioventricular orifice, being sufficient to admit the tips of four fingers. It is guarded by the tricuspid valve.

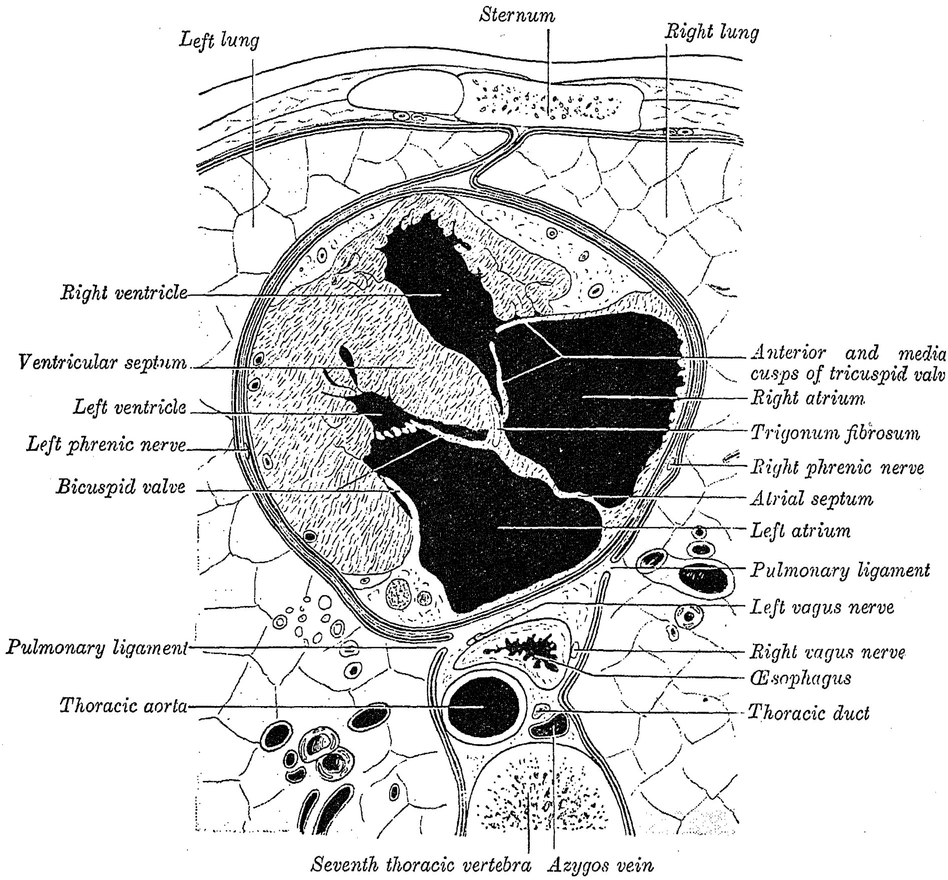
The *orifice of the pulmonary artery* is circular in form, and situated at the summit of the conus arteriosus, close to the ventricular septum. It is placed above and to the left of the atrioventricular opening, and is guarded by the pulmonary semilunar valves.

The *tricuspid valve* (figs. 639, 643) guards the right atrioventricular orifice, and consists of three somewhat triangular cusps or segments, *anterior*, *posterior and medial*; in the angles between the cusps small intermediate segments are sometimes seen. The anterior cusp, the largest, is interposed between the atrioventricular orifice and the conus arteriosus, while the medial cusp is in relation with the ventricular septum. Each cusp is formed by a duplicature of the lining membrane of the heart, strengthened by intervening layers of fibrous tissue. The central parts of the cusps are comparatively thick and strong, their marginal portions thin and translucent. Their bases are attached to the fibrous ring surrounding the atrioventricular orifice and are also joined to each other so as to form a continuous annular membrane, while their apices project into the ventricular cavity. Their atrial surfaces, directed towards the blood-current from the atrium, are smooth; their ventricular surfaces, directed towards the wall of the ventricle, are rough and irregular and, together

with the apices and margins of the cusps, give attachment to a number of delicate tendinous cords, the *chordæ tendineæ.*

The *trabeculæ carneæ* are round or irregular muscular columns which project from the whole of the inner surface of the ventricle, with the exception of the conus arteriosus, the wall of which is smooth. They are of three kinds: some are mere ridges, others are fixed at their ends but free in the middle, while a third set (*musculi papillares*) are continuous by their bases with the wall of the ventricle, while their apices project into the cavity, and give origin to the chordæ tendineæ which pass to be attached to the segments of the

FIG. 642.—A transverse section through the mediastinal cavity at the level of the body of the seventh thoracic vertebra.

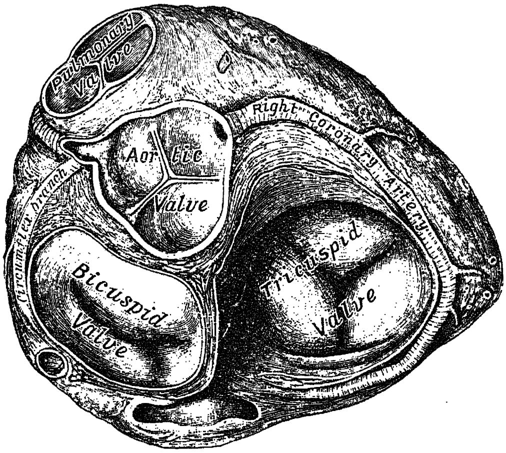


tricuspid valve. There are two papillary muscles, anterior and posterior; the anterior is the larger, and its chordæ tendineæ are connected with the anterior and posterior cusps of the valve; the posterior papillary muscle sometimes consists of two or three parts, and its chordæ tendineæ are connected with the posterior and medial cusps. Some chordæ tendineæ also spring directly from the ventricular septum, or from small papillary eminences on it, and pass to the anterior and medial cusps. A muscular band, well marked in sheep and some other animals, frequently extends from the base of the anterior papillary muscle to the ventricular septum. From its attachments it may assist in preventing over-distension of the ventricle, and so has been named the *moderator band.*

The *pulmonary semilunar valves* (figs. 639, 641) are three in number, two in front and one behind, and are formed by duplicatures of the lining membrane, strengthened by fibrous tissue. They are attached, by their convex margins,

to the wall of the pulmonary artery at its junction with the ventricle, their free borders being directed upwards into the lumen of the vessel. The free and attached margins are strengthened by tendinous fibres, and at the middle of the free margin there is a thickened nodule (*corpus Arantii*). From this nodule tendinous fibres radiate through the valve to its attached margin, but are absent from two narrow crescentic portions, the *lunulæ*, placed one on either side of the nodule immediately adjoining the free margin (fig. 644). Opposite to the semilunar valves the pulmonary artery presents three slight dilatations or sinuses (sinuses of Valsalva).

Fig. 643.—The bases of the ventricles, exposed by removal of the atria.



The **left atrium** is rather smaller than the right, but its walls are thicker, measuring about 3 mm.; it consists, like the right, of two parts, a *principal cavity* and an *auricula*.

The *principal cavity* is cuboidal in form, and concealed, in front, by the pulmonary artery and aorta. It is separated from the right atrium by the atrial septum, and opening into it on either side are the two pulmonary veins.

The *auricula* is somewhat constricted at its junction with the principal cavity; it is longer, narrower, and more curved than that of the right atrium, and its margins are more deeply indented. It is directed forwards on the left side of the pulmonary artery, and overlaps the root of this vessel.

The interior of the left atrium (fig. 645) presents the following parts for examination:

Orifices of the four pulmonary veins.
Left atrioventricular orifice.
Foramina venarum minimarum.
Musculi pectinati.

The *pulmonary veins*, four in number, open into the upper part of the posterior surface of the left atrium—two on either side of its middle line; their orifices are not provided with valves. The two left veins frequently end by a common opening.

The *left atrioventricular orifice* is the aperture between the left atrium and ventricle; it is described on p. 586.

The *foramina venarum minimarum* are the orifices of minute veins (venæ cordis minimæ) which return a small quantity of blood directly from the muscular substance of the heart.

The *musculi pectinati*, fewer and smaller than those in the right atrium, are confined to the inner surface of the auricula.

On the atrial septum may be seen a lunate impression, bounded below by a crescentic ridge, the concavity of which is directed upwards. The depression is just above the fossa ovalis of the right atrium.

The **left ventricle** is longer and more conical in shape than the right, and on transverse section its cavity presents an oval or nearly circular outline (fig. 640). It forms a small part of the sternocostal, and a considerable part of the diaphragmatic, surface of the heart; it also forms the apex of the heart. Its walls are about three times as thick as those of the right ventricle.

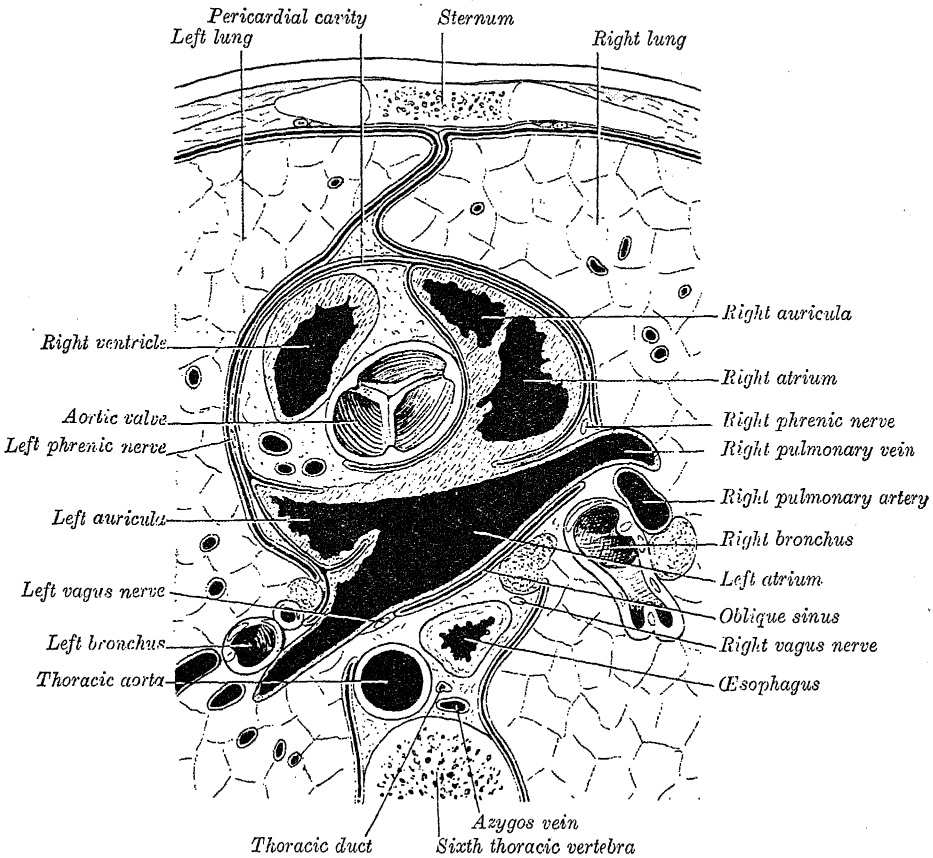
Its interior (fig. 645) presents the following parts for examination:

Orifices { Left atrioventricular. / Aortic. — Valves { Bicuspid or mitral. / Aortic.
Trabeculæ carneæ. — Chordæ tendineæ.

The *left atrioventricular orifice* is placed below and to the left of the aortic orifice. It is a little smaller than the right atrioventricular orifice, admitting the tips of only three fingers. It is surrounded by a dense fibrous ring and is guarded by the bicuspid or mitral valve.

The *aortic orifice* is a circular aperture in front and to the right of the atrioventricular orifice, from which it is separated by the anterior cusp of the bicuspid valve. Its orifice is guarded by the aortic semilunar valves. The portion of the ventricle immediately below the aortic orifice is termed the *aortic vestibule*, and possesses fibrous instead of muscular walls.

FIG. 644.—A transverse section through the mediastinal cavity at the level of the lower part of the body of the sixth thoracic vertebra.



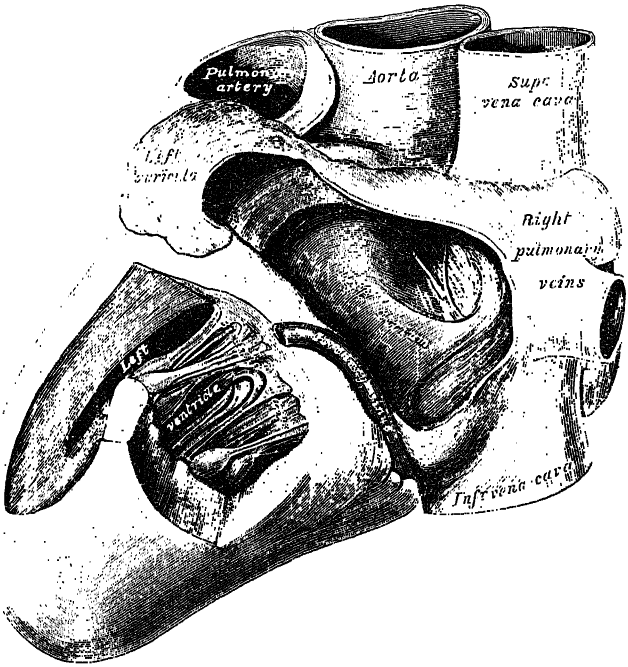
The *bicuspid or mitral valve* (figs. 643, 645) is attached to the fibrous ring which encircles the left atrioventricular orifice in the same way as the tricuspid valve is attached around the right atrioventricular orifice. It consists of two triangular cusps, formed by duplicatures of the lining membrane, strengthened by fibrous tissue, and containing a few muscular fibres. The cusps are of unequal size, and are larger, thicker, and stronger than those of the tricuspid valve. The larger cusp is placed in front and to the right between the atrioventricular and aortic orifices, and is known as the *anterior or aortic cusp*; the smaller or *posterior cusp* is placed behind and to the left of the opening. Two small cusps are usually found in the angles between the larger cusps. The cusps of the bicuspid valve are furnished with chordæ tendineæ, which are attached in a manner similar to those on the right side of the heart; they are, however, thicker, stronger, and less numerous.

The *aortic semilunar valves* (figs. 643, 646) are three in number, and surround the orifice of the aorta; two are posterior (right and left), and one anterior.

They are similar in structure, and in their mode of attachment, to the pulmonary semilunar valves, but are larger, thicker, and stronger; the lunulæ are more distinct, and the noduli or corpora Arantii thicker and more prominent. Opposite the valves the aorta presents slight dilatations, the *aortic sinuses* (sinuses of Valsalva), which are larger than those at the origin of the pulmonary artery.

The *trabeculæ carneæ* are of three kinds, like those in the right ventricle, but they are more numerous, and present a dense interlacement, especially at the apex, and upon the posterior wall, of the ventricle. The *musculi papillares* are two in number, one springing from the anterior, the other from the posterior wall; they are of large size, and end in rounded extremities from which the chordæ tendineæ arise. Chordæ tendineæ from each papillary muscle are connected to both cusps of the bicuspid valve.

FIG. 645.—The interior of the left side of the heart.



Structure.—The heart consists of muscular fibres (*myocardium*), and of fibrous rings which partly serve for their attachment. It is covered with the visceral layer of the serous pericardium (*epicardium*), and lined with the *endocardium*.

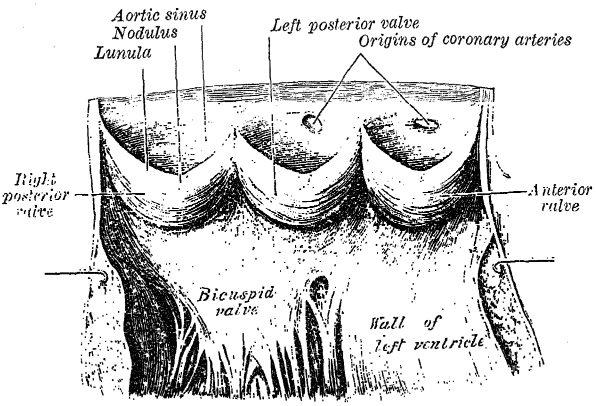
The *endocardium* is a thin, smooth, glistening membrane which lines the chambers of the heart, and is continuous with the lining membrane of the large blood-vessels; by its reduplications it assists in forming the valves. It consists of a layer of endothelial cells placed on a stratum of connective tissue and elastic fibres.

The *fibrous rings* surround the atrioventricular and arterial orifices, and are stronger on the left than on the right side of the heart. The atrioventricular rings serve for the attachment of the muscular fibres of the atria and ventricles, and for the attachment of the bicuspid and tricuspid valves. The left atrioventricular ring is closely connected, by its anterior margin, with the aortic arterial ring; between these and the right atrioventricular ring is a triangular mass of fibrous tissue, the *trigonum fibrosum*, which represents the *os cordis* of some of the larger animals, as the ox and elephant. There is also the tendon of the conus arteriosus, already referred to (p. 583).

The fibrous rings surrounding the arterial orifices serve for the attachment of the great vessels and the semilunar valves. Each ring receives, by its ventricular

margin, the attachment of some of the muscular fibres of the ventricles ; its opposite margin presents three deep semicircular notches, to which the middle coat of the artery is firmly fixed. The attachment of an artery to its fibrous ring is strengthened by the external coat of the artery and the epicardium externally, and by the endocardium internally. From the margins of the semicircular notches, the fibrous structure of the ring is continued into the segments of the valves. The middle coat of the artery in this situation is thin, and the vessel is dilated to form the sinuses of the aorta and pulmonary artery.

FIG. 646.—The aorta laid open to show the semilunar valves.

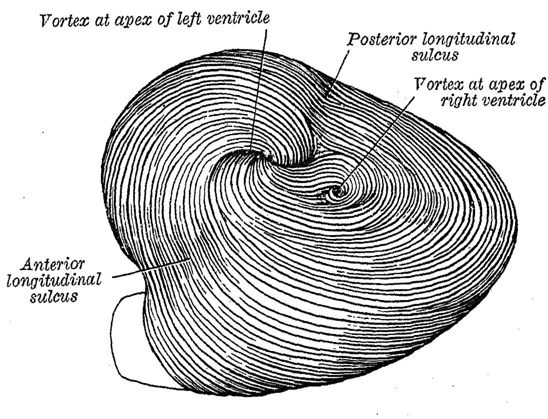


The *muscular structure of the heart* consists of fibres, which are transversely and longitudinally striated (p. 33), and present an exceedingly intricate interlacement. They comprise (*a*) the fibres of the atria, (*b*) the fibres of the ventricles, and (*c*) the atrioventricular bundle.

The *fibres of the atria* are arranged in two layers—a superficial, common to both atria, and a deep, proper to each. The *superficial fibres* are most distinct on the front of the atria, across the bases of which they run in a transverse direction, forming a thin and incomplete layer ; some of them pass into the atrial septum. The *deep fibres* consist of looped and annular fibres. The *looped fibres* pass upwards over each atrium, and are attached by their extremities to the corresponding atrioventricular ring, in front and behind ; the *annular fibres* surround the auriculæ, and form annular bands around the terminations of the veins and around the fossa ovalis.

The *fibres of the ventricles* are arranged in a complex manner, and various accounts have been given of their course and connexions ; the following description is based on that given by MacCallum.* They consist of superficial and deep layers, all of which, with the exception of two, are inserted into the papillary muscles of the ventricles. The *superficial layers* comprise the following : (*a*) Fibres which spring from the tendon of the conus arteriosus (p. 583) and sweep downwards and towards the left across the anterior longitudinal sulcus and around the apex of the heart, where they form a vortex (fig. 647) and pass upwards and inwards to terminate in the papillary muscles of the left ventricle ; those arising from the upper half of the tendon of the conus arteriosus pass to the anterior papillary muscle, those from the lower half to the posterior papillary muscle and the papillary muscles of the septum (fig. 648). (*b*) Fibres which arise from the right atrioventricular ring and run diagonally across the diaphragmatic surface of the right ventricle and round its right border on to its sternocostal surface, where they dip

FIG. 647.—The two vortices at the apex of the heart. (Mall.)



* John Bruce MacCallum, *Johns Hopkins Hospital Reports*, vol. ix.

beneath the fibres just described, and, crossing the anterior longitudinal sulcus, wind around the apex of the heart and end in the posterior papillary muscle of the left ventricle. (*c*) Fibres which spring from the left atrioventricular ring, and, crossing the posterior longitudinal sulcus, pass successively into the right ventricle and end in its papillary muscles. The *deep layers* are three in number; they arise in the papillary muscles of one ventricle and, curving in an S-shaped manner, turn in at the longitudinal sulcus and end in the papillary muscles of the other ventricle (fig. 649). The layer which is most superficial in the right ventricle lies next the lumen of the left, and vice versa. Those of the first layer almost encircle the right ventricle, and, crossing in the septum to the left ventricle, unite with the superficial fibres from the right atrioventricular ring to form the posterior papillary muscle. Those of the second layer have a less extensive course in the wall of the right ventricle, and a correspondingly greater course in the left, where they join with the superficial fibres from the anterior half of the tendon of the conus arteriosus to form the papillary muscles of the septum. Those of the third layer pass almost entirely round the left ventricle and unite with the superficial fibres from the lower half of the tendon of the conus arteriosus to form the anterior papillary muscle. Besides the layers just described there are two bands which do not end in papillary muscles. One springs from the right atrioventricular ring, crosses in the atrioventricular septum, encircles the deep layers of the left ventricle, and ends in the left atrioventricular ring. The second band is apparently confined to the left ventricle; it is attached to the left atrioventricular ring, and encircles the portion of the ventricle adjacent to the aortic orifice.*

Fig. 648.—A diagram of the superficial muscular fibres of the ventricles of the heart originating in the tendon of the conus arteriosus. (After MacCallum.)

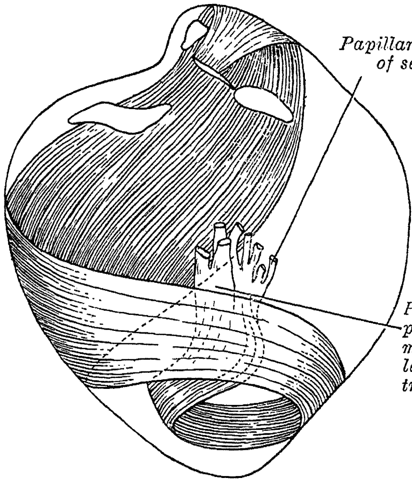
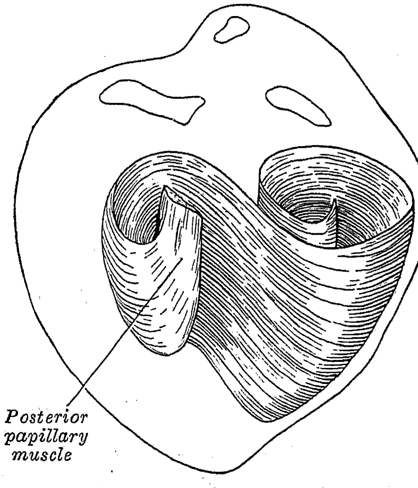


Fig. 649.—A diagram of the course of the deepest layer of muscular fibres of the left ventricle. (After MacCallum.)

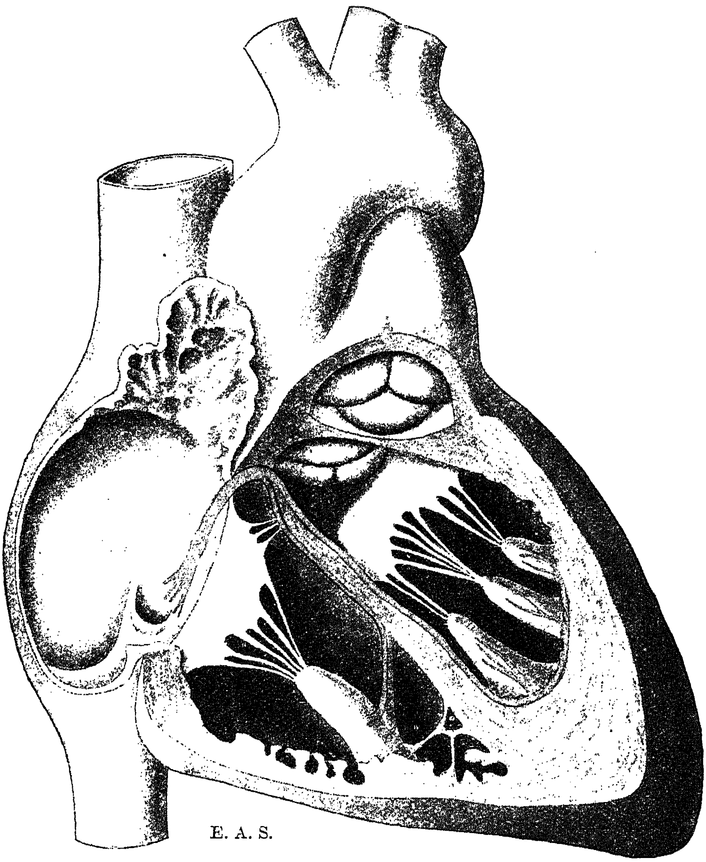


The *atrioventricular bundle* (fig. 650) is a direct muscular connexion between the atria and the ventricles. It arises in association with two small collections of spindle-shaped cells, the sino-atrial and atrioventricular nodes. The *sino-atrial node* is situated on the right border of the opening of the superior vena cava in the upper part of the sulcus terminalis; from it strands of fusiform fibres run under the endocardium of the wall of the right atrium to the *atrioventricular node* which lies near the orifice of the coronary sinus in the annular and septal fibres of the right atrium. From the atrioventricular node the atrioventricular bundle passes forwards below the membranous septum, and divides into right and left fasciculi. These run down in

* Franklin P. Mall gives an account of his researches 'On the muscular architecture of the ventricles of the human heart' in the *American Journal of Anatomy*, vols. 11 and 13.

the right and left ventricles, one on either side of the ventricular septum, covered with endocardium. The right fasciculus passes into the moderator band, and breaks up into numerous strands which end in an intricate network on the papillary muscles and on the wall of the right ventricle. The left fasciculus consists of two main strands, an anterior and a posterior, which are distributed to the papillary muscles and the wall of the left ventricle. The atrioventricular bundle and its divisions are enveloped in a sheath of connective tissue; by injecting this sheath with Indian ink the ramifications of the bundle can be demonstrated. The nodes and greater portion of the bundle consists of narrow, somewhat fusiform fibres, but the terminal strands of the bundle are composed of Purkinje fibres.

FIG. 650.—A schematic representation of the atrioventricular bundle. The course of the bundle is represented in red.



Kent has described a second atrioventricular bundle in the right lateral aspect of the heart, containing cardiac muscle-fibres, fine nerve-fibres, and fibres resembling those of Purkinje. This bundle is connected with a node in the wall of the right atrium, formed of fine, faintly striated muscle-fibres.

A. Morison * has shown that in the sheep and pig the atrioventricular bundle 'is a great avenue for the transmission of nerves from the auricular to the ventricular heart'; large and numerous nerve-trunks enter the bundle and course with it. Branches arise from these nerve-trunks and form plexuses around groups of Purkinje cells, and from these plexuses fine fibrils go to innervate individual cells.

The sino-atrial and atrioventricular nodes, the atrioventricular bundle and its right fasciculus, are supplied by the right coronary artery; the left fasciculus of the bundle is supplied by both coronary arteries.

* *Journal of Anatomy and Physiology*, vol. xlvi.

Applied Anatomy.—Clinical and experimental evidence go to prove that this bundle conveys the impulse to systolic contraction from the atrial septum to the ventricles, and much attention has been paid to it, because it appears to become fibrosed and to lose much of its conducting power (heart-block) in many cases of Adams-Stokes' syndrome. This condition is characterised by a slow pulse, a tendency to syncopal or epileptiform seizures, and the fact that while the cardiac atria beat at a normal rate, the ventricles contract much less frequently.

Vessels and Nerves.—The *arteries* supplying the heart are the right and left coronary branches of the aorta (p. 598); the majority of the *veins* are drained by the coronary sinus into the right atrium.

The *lymphatic* vessels are described on p. 778.

The *nerves* are derived from the cardiac plexus (p. 978), which is formed by branches from the vagi and sympathetic. They are freely distributed both on the surface and in the substance of the heart, the separate nerve-filaments being furnished with small ganglia. The atrioventricular bundle receives nerve-fibres from ganglia in the atrial septum. Other ganglia are found in relation with the sino-atrial node, and supply it with nerve-filaments.

The cardiac cycle and the actions of the valves.—By the contractions of the heart the blood is pumped through the arteries to all parts of the body. These contractions occur regularly and at the rate of about seventy per minute. Each wave of contraction or *period of activity* is followed by a *period of rest*, the two periods constituting what is known as a *cardiac cycle*.

Each cardiac cycle consists of three phases, which succeed each other as follows: (1) a short simultaneous contraction of both atria, termed the *atrial systole*, followed, after a slight pause, by (2) a simultaneous, but more prolonged, contraction of both ventricles, named the *ventricular systole*, and (3) a *period of rest*, during which the whole heart is relaxed. The atrial contraction commences around the venous openings, and sweeping over the atria forces their contents through the atrio-ventricular openings into the ventricles, regurgitation into the veins being prevented by the contraction of their muscular coats. When the ventricles contract, the tricuspid and bicuspid valves are closed, and prevent the passage of the blood back into the atria; the musculi papillares at the same time are shortened, and, pulling on the chordæ tendineæ, prevent the inversion of the valves into the atria. As soon as the pressure in the ventricles exceeds that in the pulmonary artery and aorta, the valves guarding the orifices of these vessels are opened, and the blood is driven from the right ventricle into the pulmonary artery, and from the left into the aorta. The moment the systole of the ventricles ceases, the pressure of the blood in the pulmonary artery and aorta closes the pulmonary and aortic semilunar valves, thus preventing regurgitation of blood into the ventricles, and the valves remain shut until re-opened by the next ventricular systole. During the period of rest the tension of the tricuspid and bicuspid valves is relaxed, and blood flows from the veins through the atria into the ventricles. The filling of the ventricles is completed by the systole of the atria. The average duration of a cardiac cycle is about $\frac{8}{10}$ of a second, made up as follows:

Atrial systole, $\frac{1}{10}$.	Atrial diastole, $\frac{7}{10}$.
Ventricular systole, $\frac{3}{10}$.	Ventricular diastole, $\frac{5}{10}$.
Total systole, $\frac{4}{10}$.	Complete diastole, $\frac{4}{10}$.

The rhythmical action of the heart is *muscular* in origin—that is to say, the heart-muscle possesses the inherent property of contraction apart from any nervous stimulation. The more embryonic the muscle the better is it able to initiate the contraction wave, and the normal systole of the heart starts at the sino-atrial node, where the muscle is most embryonic in nature: for this reason the sino-atrial node has been called the "pace-maker" of the heart. A slight pause occurs between systole of the atria and that of the ventricles. This is due to the fact that the contraction of the ventricles is excited by an impulse conveyed by the atrioventricular bundle, conduction along the fibres of which is relatively slow. The nerves, although not concerned in originating the contractions of the heart-muscle, play an important rôle in regulating their force and frequency in order to subserve the physiological needs of the organism.

Applied Anatomy.—Wounds of the heart are often immediately fatal, but not necessarily so. They may be non-penetrating, when death may occur from hæmorrhage if one of the coronary vessels has been wounded, or subsequently from pericarditis. Even a

penetrating wound is not necessarily fatal, as many cases have been recorded in which the wound has been sutured successfully. When blood is effused into the pericardial sac it presses especially on the thin-walled atria, and so interferes with the circulation through the heart.

The Chief Peculiarities in the Vascular System of the Fœtus

The development of the heart and vascular system is described on pp. 109 to 132.

The chief peculiarities of the fœtal heart are the communication between the atria through the foramen ovale, and the large size of the valve of the inferior vena cava. The following points may also be noted: (1) In early fœtal life the heart lies immediately below the mandibular arch, and as development proceeds it is gradually drawn within the thorax. (2) For a time the atrial portion exceeds the ventricular in size, and the walls of the ventricles are of equal thickness, since each ventricle bears the pressure of the systemic circulation. Towards the end of fœtal life the ventricular portion becomes the larger, and the wall of the left ventricle exceeds that of the right in thickness, thus becoming adapted to bear the pressure of the whole systemic circulation. (3) Its size is large as compared with that of the rest of the body, the proportion at the second month of fœtal life being 1 to 50; at birth 1 to 120; in the adult about 1 to 160.

The *foramen ovale* is an opening between the atria until the end of fœtal life; it is obliterated shortly after birth (p. 115).

The *valve of the inferior vena cava* directs the blood from the inferior vena cava through the foramen ovale into the left atrium.

The chief peculiarities in the arterial system of the fœtus are (1) the communication between the pulmonary artery and the aorta by means of the ductus arteriosus, and (2) the continuation of the hypogastric arteries as the umbilical arteries to the placenta.

The *ductus arteriosus* is a short tube, about 1 cm. in length at birth, and of the diameter of a goose-quill. In early fœtal life it forms the continuation of the pulmonary artery, and opens into the aorta, just beyond the origin of the left subclavian artery; and so conducts a great part of the blood from the right ventricle into the aorta. When the branches of the pulmonary artery have become larger relatively to the ductus arteriosus, the latter is chiefly connected to the left pulmonary artery. It is obliterated within a few days after birth.

In the fœtus the *hypogastric arteries* are continued along the sides of the urinary bladder, thence upwards on the back of the anterior abdominal wall to the umbilicus, through which they pass out of the abdomen and run, under the name of the *umbilical arteries*, in the umbilical cord to the placenta. They convey blood from the fœtus to the placenta.

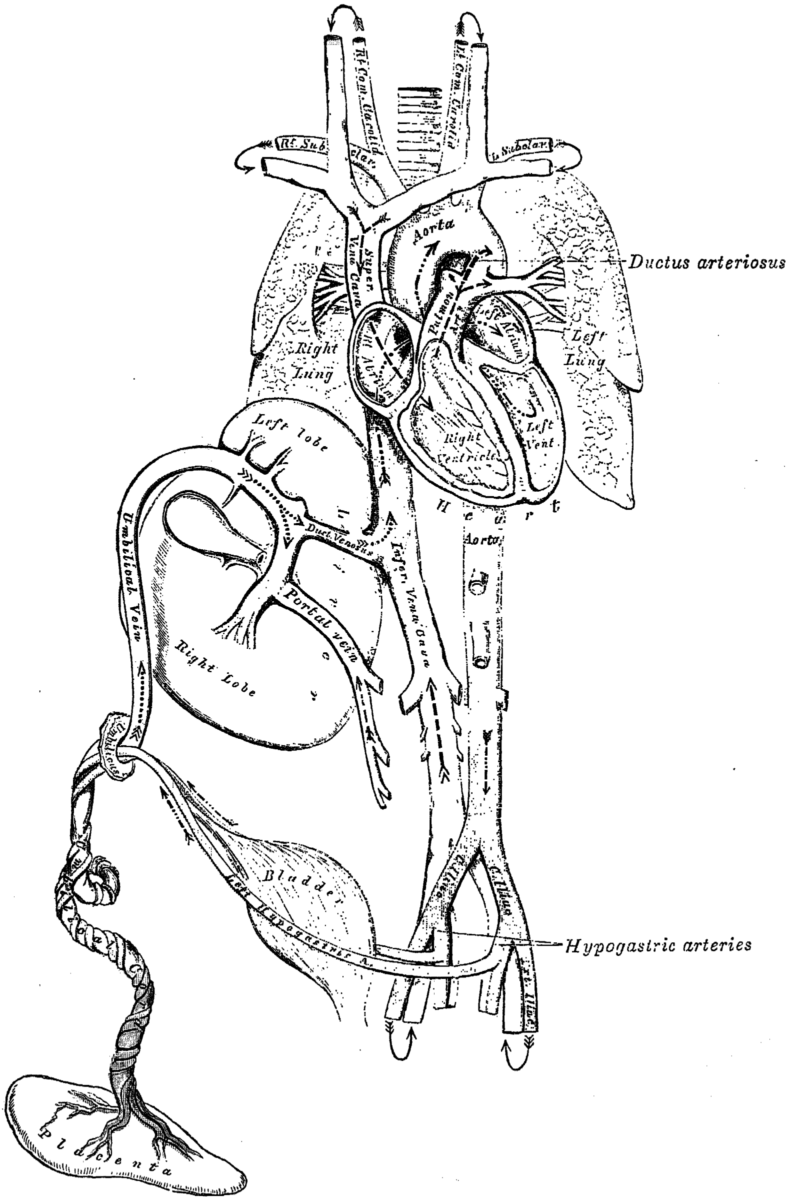
The chief peculiarities in the venous system of the fœtus are the communications established between the placenta and the liver and portal vein, through the umbilical vein; and between the umbilical vein and the inferior vena cava through the ductus venosus.

The Fœtal Circulation (fig. 651)

The fœtal blood is carried to the placenta by the umbilical arteries, and returned from the placenta to the fœtus by the two umbilical veins. These veins unite in the umbilical cord to form a single vein (vena umbilicalis impar) which divides within the embryo into a right and a left umbilical vein. After the formation of the liver the right umbilical vein atrophies and disappears, but the left persists until the end of fœtal life. It enters the abdomen at the umbilicus, and passes along the free margin of the falciform ligament of the liver, to the visceral surface of that organ, where it gives off two or three branches, one of large size to the left lobe, and others to the lobus quadratus and lobus caudatus. At the porta hepatis (transverse fissure of the liver) it divides into two branches; of these, the larger is joined

by the portal vein, and enters the right lobe ; the smaller is continued upwards under the name of the ductus venosus, and joins the inferior vena cava. The blood conveyed by the left umbilical vein passes to the inferior vena cava in

FIG. 651.—A plan of the fœtal circulation.



In this plan the arrows represent the course which the blood takes in the heart and vessels.

three different ways. Some enters the liver directly and is carried to the inferior vena cava by the hepatic veins ; a considerable quantity circulates through the liver with the portal venous blood, before entering the inferior vena cava by the hepatic veins ; the remainder passes directly into the inferior vena cava through the ductus venosus.

In the inferior vena cava, the blood carried by the ductus venosus and hepatic veins mixes with that returning from the lower extremities and

abdominal wall. It enters the right atrium, and, guided by the valve of the inferior vena cava, passes through the foramen ovale into the left atrium, where it mingles with a small quantity of blood returned from the lungs by the pulmonary veins. From the left atrium it passes into the left ventricle, and from that cavity into the aorta, by means of which it is distributed almost entirely to the head and upper extremities, a small quantity being probably carried into the descending aorta. The blood from the head and upper extremities is returned by the superior vena cava to the right atrium, where it mixes with a small portion of that returned by the inferior vena cava. From the right atrium the blood passes into the right ventricle, and thence into the pulmonary artery. The lungs of the fœtus being inactive, only a small quantity of the blood conveyed by the pulmonary artery is distributed to them by the right and left pulmonary arteries, and returned by the pulmonary veins to the left atrium: the greater part passes through the ductus arteriosus into the aorta, where it mixes with the small quantity of blood transmitted by the left ventricle into this part of the aorta. It descends through the aorta and is in part distributed to the lower extremities and the viscera of the abdomen and pelvis, but most of it is conveyed by the umbilical arteries to the placenta.

From the preceding account of the circulation of the blood in the fœtus the following facts will be inferred: 1. The placenta serves the purposes of nutrition and excretion, receiving the impure blood from the fœtus, and returning it purified and charged with nutritive material. 2. A large part of the blood of the left umbilical vein traverses the liver before entering the inferior vena cava; this is correlated with the relatively large size of the liver, especially at an early period of fœtal life. 3. The right atrium is the point of meeting of a double current, the blood from the inferior vena cava being guided by the valve of this vessel through the foramen ovale into the left atrium, while that in the superior vena cava descends into the right ventricle. At an early period of fœtal life it is highly probable that the two streams are quite distinct, for the inferior vena cava opens almost directly into the left atrium, and the valve of the inferior vena cava would exclude the current from the right ventricle. At a later period, as the separation between the two atria becomes more marked, it seems probable that some mixture of the two streams must take place. 4. The pure blood carried from the placenta to the fœtus, mixed with the blood from the portal vein and inferior vena cava, passes almost directly to the arch of the aorta, and is distributed by the branches of that vessel to the head and upper extremities. 5. The blood contained in the descending aorta, chiefly derived from that which has already circulated through the head and limbs, together with a small quantity from the left ventricle, is distributed to the abdomen and lower extremities.

The Changes in the Vascular System at Birth

At birth, when respiration is established, an increased amount of blood from the pulmonary artery passes through the lungs, and the placental circulation is cut off. The foramen ovale is closed by the septum secundum (p. 115) about the tenth day after birth; sometimes a slit-like opening is left between the two atria.

The *ductus arteriosus* begins to contract immediately after respiration is established, and is completely closed between the fourth and fifth days after birth; it ultimately forms an impervious cord, the *ligamentum arteriosum*, which connects the left pulmonary artery to the arch of the aorta.

The parts of the *hypogastric arteries* extending from the sides of the bladder to the umbilicus become obliterated between the second and fifth days after birth, and project towards the abdominal cavity as fibrous cords; these cords are termed the lateral umbilical ligaments, and are enveloped by folds of peritoneum.

The *left umbilical vein* and the *ductus venosus* are completely obliterated between the second and fifth days after birth; the former becomes the ligamentum teres, the latter the ligamentum venosum, of the liver.

THE ARTERIES

The distribution of the systemic arteries is like a highly branched tree, the common trunk of which, formed by the aorta, commences at the left ventricle, while the smallest ramifications extend to the viscera and to the peripheral parts of the body. Arteries are found in all parts of the body, except in the hairs, nails, epidermis, cartilages, and corneæ; the larger trunks usually occupy the most protected situations, running, in the limbs, along the flexor surfaces, where they are less exposed to injury.

There is considerable variation in the mode of division of the arteries: occasionally a short trunk subdivides into several branches at the same point, as in the cœliac artery and the thyreocervical trunk; more usually the vessel gives off several branches in succession, and still continues as the main trunk, as in the arteries of the limbs.

A branch of an artery is smaller than the trunk from which it arises; but if an artery divides into two branches, the combined sectional area of the two vessels is, in nearly every instance, somewhat greater than that of the trunk; and the combined sectional area of all the arterial branches greatly exceeds that of the aorta.

The arteries unite with one another, forming what are called *anastomoses*. Anastomosis between trunks of nearly equal size is found in the brain, where the two vertebral arteries unite to form the basilar artery, and the two anterior cerebral arteries are connected by the anterior communicating artery; and in the abdomen, where the intestinal arteries have free anastomoses between their larger branches. In the limbs, the anastomoses are largest and most numerous around the joints; the branches arising from an artery above a joint uniting with branches from the vessels below it. These anastomoses are of considerable interest to the surgeon, as it is by their enlargement that a *collateral circulation* is established after the application of a ligature to a main artery. The smaller branches of arteries anastomose more frequently than the larger; and between the smallest twigs these anastomoses may be so numerous that they constitute a close network. In certain regions of the body, however, there are arteries which have no anastomoses with neighbouring arteries except through the agency of the capillaries. Such are found in the spleen and kidney, and in certain parts of the brain, and are called *end arteries.* If an artery of this type be occluded, serious nutritional disturbances resulting in death (necrosis) will occur in the terrtiory supplied by the vessel.

Applied Anatomy.—The walls of all the arteries, and most of all of the aorta, are liable to various forms of hardening with loss of elasticity, known collectively as *arteriosclerosis*, that are of the greatest clinical importance. The two chief varieties of arteriosclerosis are: (1) hypertrophy of the muscular tunica media of the arteries, clinically associated with chronic arterial vasoconstriction and high blood-pressure, and (2) atheroma or atherosclerosis, essentially a senile degenerative change of the intima, that leads to loss of arterial elasticity by the replacement of elastic by fibrous tissue. Whatever the cause of arterial sclerosis its chief ill-effects on the patient are two. In the first place, it is associated with a permanent and often considerable rise in the arterial blood-pressure, entailing a corresponding hypertrophy of the heart; in the second, it weakens the vessel walls, rendering them more liable to rupture, while at the same time it is apt to lessen the calibre of the affected vessels.

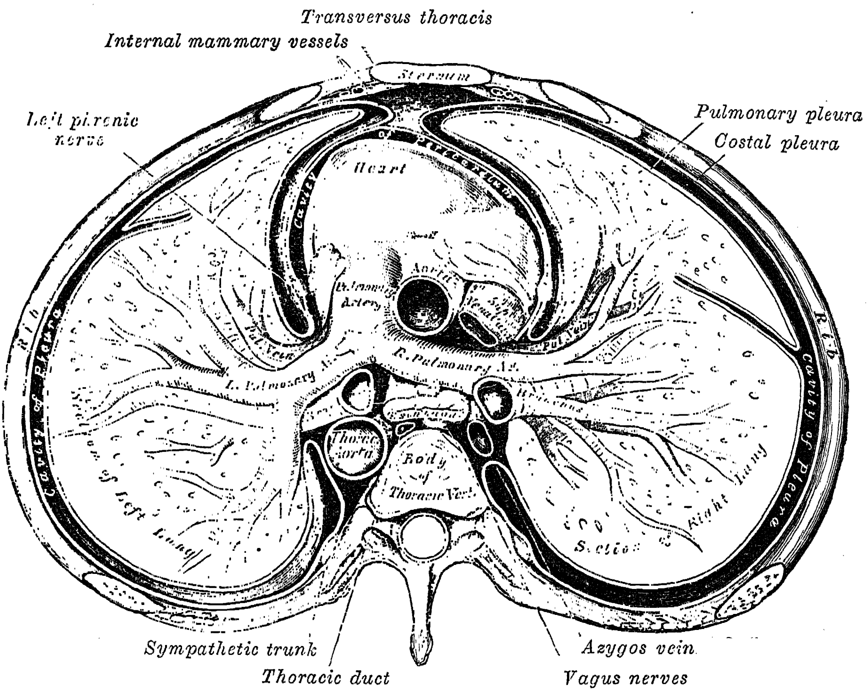
The arteries are also frequently attacked by syphilis, which gives rise to inflammation and degeneration of their middle coats. Arterial aneurysms, other than those due to direct injury, occur almost solely in syphilitic patients.

The Pulmonary Artery

The **pulmonary artery** (figs. 652, 653) conveys venous blood from the right ventricle of the heart to the lungs. It is about 5 cm. in length and 3 cm. in diameter, and arises from the conus arteriosus of the right ventricle. It runs upwards and backwards, passing at first in front and then to the left of the ascending aorta, as far as the under surface of the aortic arch, where it divides, about the level of the fibrocartilage between the fifth and sixth thoracic vertebræ, into right and left branches of nearly equal size.

Relations.—The whole of the pulmonary artery is contained within the pericardium. It and the ascending aorta are enclosed in a common tube of the visceral layer of the serous pericardium. The fibrous layer of the pericardium is gradually lost upon the external coats of the two branches of the artery. In front, the pulmonary artery is separated from the anterior end of the second left intercostal space by the pleura, the left lung, and the pericardium; it rests at first upon the ascending aorta; higher up it lies in front of the left atrium, and the ascending aorta is on its right side. On either side of its origin is the auricula of the corresponding atrium, and a coronary artery; the left coronary artery, in the first part of its course passes behind the vessel. The superficial part of the cardiac plexus lies between the division of the pulmonary artery and the arch of the aorta.

FIG. 652.—A transverse section through the thorax, showing the relations of the pulmonary artery, etc. Diagrammatic.



The **right branch** of the pulmonary artery, slightly longer and larger than the left, runs horizontally to the right, behind the ascending aorta, superior vena cava, and upper right pulmonary vein, and in front of the right bronchus, to the root of the right lung, where it divides into two branches. The lower and larger of these is distributed to the middle and lower lobes of the lung; the upper and smaller accompanies the eparterial bronchus to the upper lobe.

The **left branch** of the pulmonary artery, a little shorter and smaller than the right, runs horizontally in front of the descending aorta and left bronchus to the root of the left lung, where it divides into two branches, one for either lobe of the lung. Above, it is united to the concavity of the aortic arch by the ligamentum arteriosum, on the left of which is the left recurrent nerve, and on the right the superficial part of the cardiac plexus. Below, it is joined to the upper left pulmonary vein by the ligament of the left vena cava (p. 576).

The terminal branches of the pulmonary arteries are described with the anatomy of the lungs.

Applied Anatomy.—Stenosis (narrowing) or atresia (non-perforation) of the pulmonary orifice, usually combined with other developmental anomalies such as defect of the upper part of the interventricular septum, patency of the ductus arteriosus, or patency of the

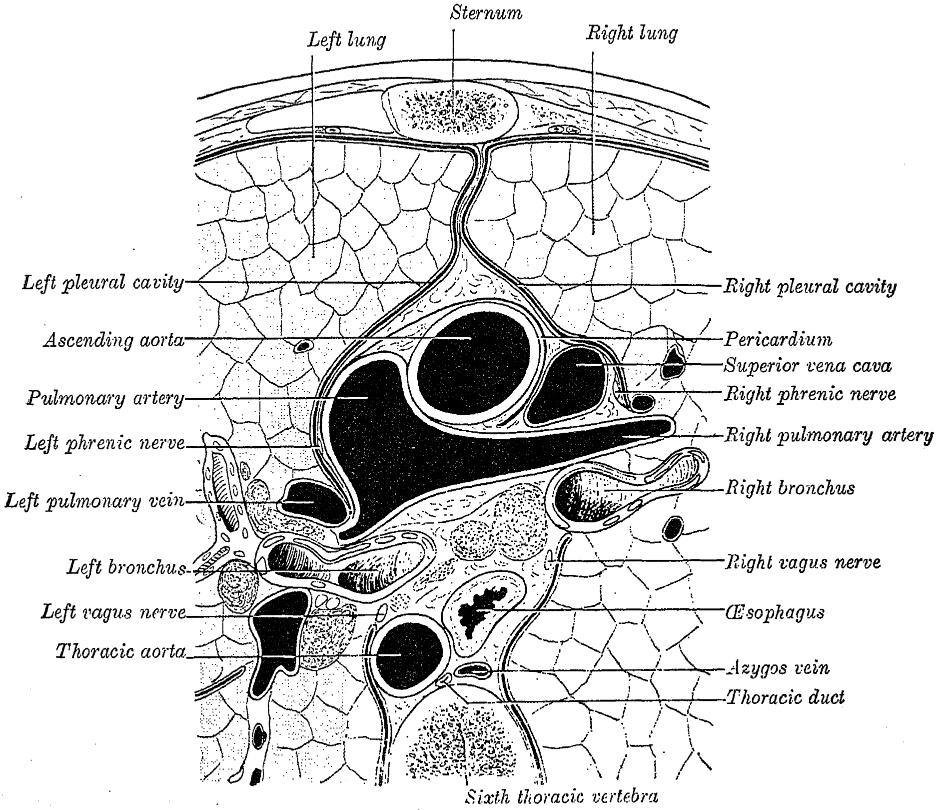
foramen ovale, is the commonest form of congenital heart disease. It is due to maldevelopment, and not to fœtal endocarditis; possibly, as Keith suggests, to malformation of the bulbus cordis. In well-marked cases the child with congenital heart disease is cyanosed, short of breath on exertion, and puny, generally dying of sudden heart failure or bronchitis before adolescence. The chief signs of the condition are the loud, harsh systolic cardiac murmur best heard over the second left costal cartilage, cyanosis, clubbing of the finger-tips, and the presence of an excess of red corpuscles in the blood.

Embolism of the pulmonary artery by a clot of blood coming from the right side of the heart in patients with heart-disease, or from a thrombosed vein in cases, for example, of influenza, enteric fever, puerperal sepsis, or fractured limbs, is a common cause of sudden or rapid death. The patient may cry out with sudden excruciating pain in the precordia when the detached embolus lodges, and after a brief period of intense dyspnœa, pallor, and anguish, die.

The Aorta

The **aorta** is the main trunk of the series of vessels which convey the oxygenated blood to the tissues of the body. It begins at the upper part of the left ventricle, where it is about 3 cm. in diameter, and after ascending for

Fig. 653.—A transverse section through the mediastinal cavity at the level of the upper part of the body of the sixth thoracic vertebra.

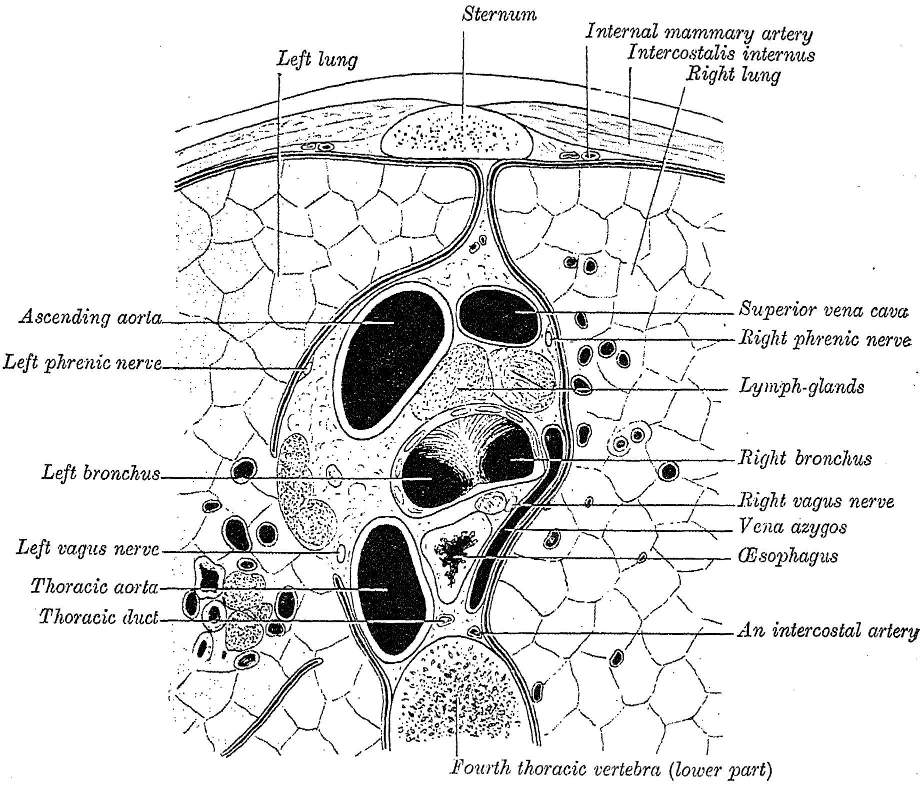


a short distance, arches backwards and to the left, over the root of the left lung; it then descends within the thorax on the left side of the vertebral column, and enters the abdominal cavity through the aortic hiatus in the Diaphragm. Considerably diminished in size (about 1·75 cm. in diameter), it ends, on the left of the median plane, at the level of the lower border of the fourth lumbar vertebra, by dividing into the right and left common iliac arteries. Hence it is described in several portions, viz. the *ascending aorta*, the *arch of the aorta*, and the *descending aorta*, which last is divided into the *thoracic* and *abdominal aortæ*.

The Ascending Aorta

The **ascending aorta** (figs. 635, 655) is about 5 cm. long. It begins at the base of the left ventricle, on a level with the lower border of the third costal cartilage, behind the left half of the sternum; it passes obliquely upwards, forwards, and to the right behind the sternum, in the direction of the heart's axis, as high as the upper border of the second right costal cartilage, describing a slight curve in its course. At its origin it presents, opposite the segments of the aortic valve, three small dilatations called the aortic sinuses. At the union of the ascending aorta with the aortic arch the

Fig. 654.—A transverse section through the mediastinal cavity at the level of the lower part of the body of the fourth thoracic vertebra.



calibre of the vessel is slightly increased, owing to a bulging of its right wall. This dilatation is termed the *bulb of the aorta*, and on transverse section at this level, the vessel presents a somewhat oval figure.

Relations.—The ascending aorta is contained within the pericardium, and is enclosed in a tube of the serous pericardium, common to it and the pulmonary artery. It is covered at its commencement by the trunk of the pulmonary artery and the right auricula, and, higher up, is separated from the sternum by the pericardium, the right pleura, the anterior margin of the right lung, some loose areolar tissue, and the remains of the thymus; *posterior* to it are the left atrium, the right pulmonary artery, and the right bronchus. On its *right side* are the superior vena cava and right atrium, the former lying partly behind it; on its *left side* is the pulmonary artery.

Branches.—The branches of the ascending aorta are the right and left coronary arteries (figs. 638, 655) which supply the heart; they arise from the aortic sinuses immediately above the attached margins of the aortic semilunar valves.

The **right coronary artery** arises from the anterior aortic sinus. It passes at first between the conus arteriosus and the right auricula and then runs in the right

portion of the coronary sulcus, coursing on the front of the heart from left to right, and then on the back of the heart from right to left as far as the posterior longitudinal sulcus; under the name of the *posterior descending branch* it proceeds down this sulcus, sometimes as far as the apex of the heart. The right coronary artery gives off a large *marginal branch* which follows the acute margin of the heart towards the apex, and ramifies on both surfaces of the right ventricle. It also supplies branches to the right atrium and to the part of the left ventricle which adjoins the posterior longitudinal sulcus.

FIG. 655.—The arch of the aorta, and its branches.

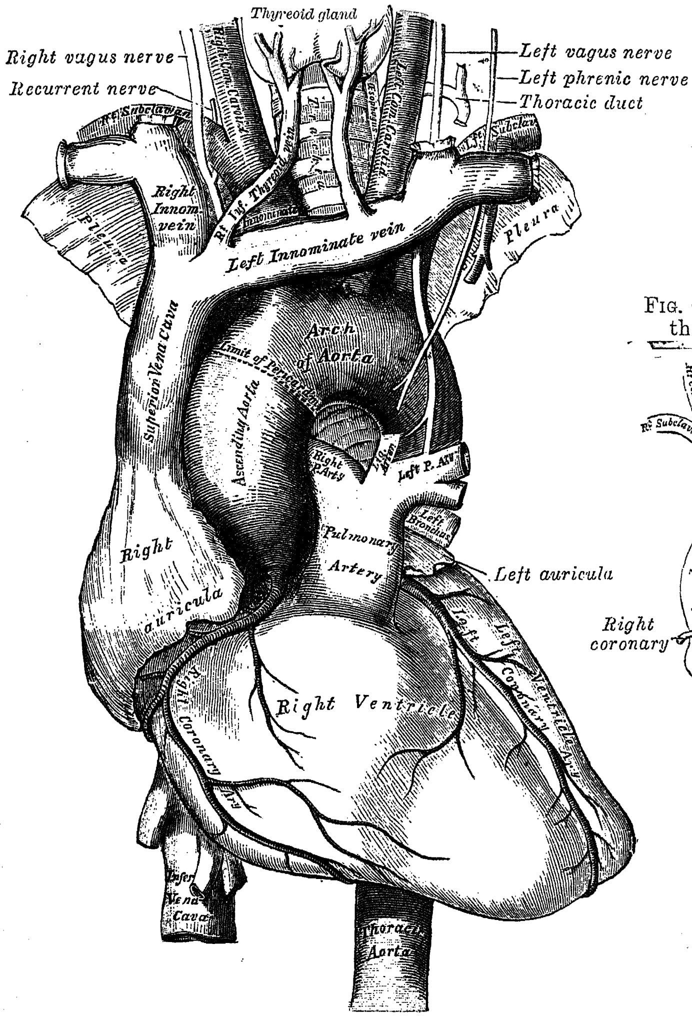
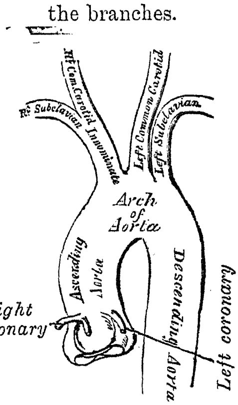


FIG. 656.—Plan of the branches.



The **left coronary artery**, larger than the right, arises from the left posterior aortic sinus and, after a short forward course between the pulmonary artery and the left auricula, divides into an anterior descending and a circumflex branch. The *anterior descending branch* runs forwards between the pulmonary artery and the left auricula, and reaching the anterior longitudinal sulcus, descends in it to the incisura apicis cordis; it gives branches to both ventricles. In many subjects the anterior descending branch turns round the apex (fig. 638) and ascends for a varying distance in the posterior longitudinal sulcus. The *circumflex branch* follows the left part of the coronary sulcus, running first to the left and then to the right, reaching nearly as far as the posterior longitudinal sulcus; it gives branches to the left atrium and ventricle.

There is a very free anastomosis between the minute branches and between the capillaries of the two coronary arteries in the substance of the heart.*

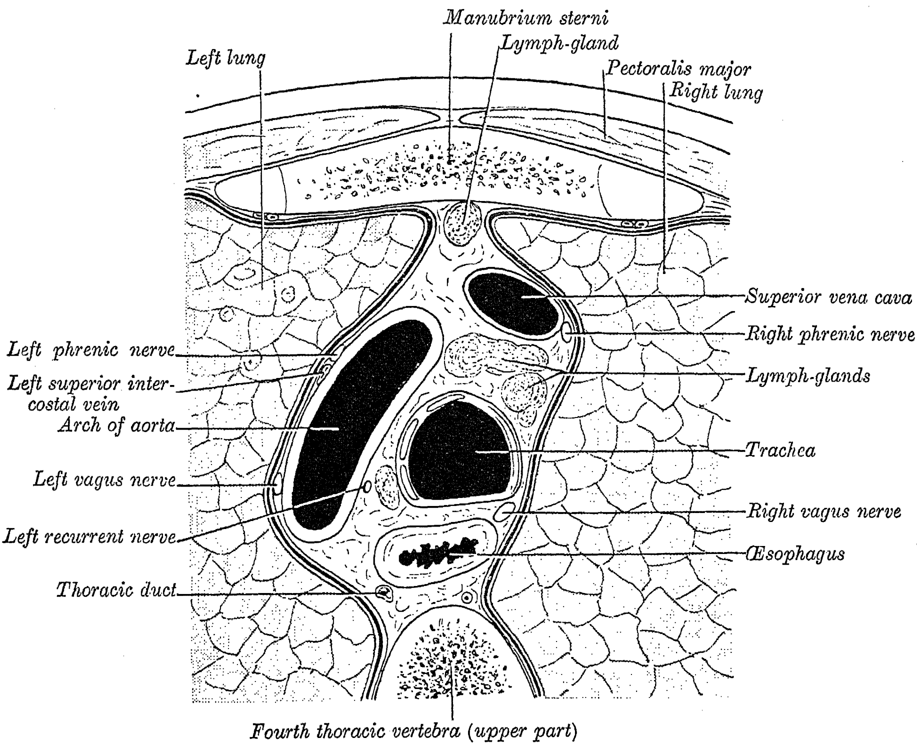
Peculiarities.—The coronary arteries occasionally arise by a common trunk; their number may be increased to three or four.

Applied Anatomy.—The sudden blocking of a coronary artery by an embolus, or its more gradual obstruction by arterial disease or thrombosis, is a common cause of sudden death in persons past middle age. If the obstruction to the passage of blood is incomplete, *angina pectoris* may occur. In this condition the patient is suddenly seized with a spasm of agonising pain in the precordial region and down the left arm, together with an indescribable sense of anguish. He may die in such an attack, or succumb a few hours or days later from heart failure, or survive a number of attacks.

The Arch of the Aorta

The **arch of the aorta** (figs. 655, 657) connects the ascending with the descending aorta; it begins at the level of the upper border of the second right sternocostal articulation, and runs at first upwards, backwards, and to the left in front of the trachea; it is then directed backwards on the left side of

Fig. 657.—A transverse section through the mediastinal cavity at the level of the upper part of the body of the fourth thoracic vertebra.



the trachea, and finally passes downwards on the left side of the body of the fourth thoracic vertebra, at the lower border of which it is continuous with the descending aorta. It thus forms two curvatures: one with its convexity upwards, the other with its convexity forwards and to the left. Its upper border is usually about 2·5 cm. below the superior border of the manubrium sterni.

Relations.—The arch of the aorta is covered *anteriorly* by the pleuræ and anterior margins of the lungs, and by the remains of the thymus. As the vessel runs backwards its *left* side is in contact with the left lung and pleura. Passing

* Consult in this connexion 'The blood-supply of the heart' by Louis Gross, 1921.

downwards on the left side of this part of the arch are four nerves; in order from before backwards these are: the left phrenic, the lower of the superior cardiac branches of the left vagus, the superior cardiac branch of the left sympathetic, and the trunk of the left vagus. As the left vagus crosses the arch it gives off its recurrent branch which hooks round below the vessel and then passes upwards on its right side. The left superior intercostal vein runs obliquely upwards and forwards on the left side of the arch, between the phrenic and vagus nerves. On the *right* are the deep part of the cardiac plexus, the left recurrent nerve, and the œsophagus; the trachea lies behind and to the right of the vessel. *Above* are the innominate, left common carotid, and left subclavian arteries, which arise from the convexity of the arch and are crossed close to their origins by the left innominate vein. *Below* are the bifurcation of the pulmonary artery, the left bronchus, the ligamentum arteriosum, the superficial part of the cardiac plexus, and the left recurrent nerve. As already stated (p. 596), the ligamentum arteriosum connects the commencement of the left pulmonary artery to the aortic arch.

In the fœtus the lumen of the aorta is considerably narrowed between the origin of the left subclavian artery and the attachment of the ductus arteriosus, forming what is termed the *aortic isthmus*, while immediately beyond the ductus arteriosus the vessel presents a fusiform dilatation which His has named the *aortic spindle*—the point of junction of the two parts being marked in the concavity of the arch by an indentation or angle. These conditions persist, to some extent, in the adult, where His found that the average diameter of the spindle exceeded that of the isthmus by 3 mm.

Peculiarities.—The summit of the arch of the aorta is usually about 2·5 cm. below the upper border of the sternum; but it may reach nearly to the top of the bone. Occasionally it is found 4 cm., more rarely from 5 to 8 cm., below this point. Sometimes the aorta arches over the root of the right lung (right aortic arch) instead of over that of the left, and passes down on the right side of the vertebral column, a condition which is normal in birds. In such cases there is a transposition of the thoracic and of the abdominal viscera. Less frequently the aorta, after arching over the root of the right lung, is directed to its usual position on the left side of the vertebral column; this peculiarity is not accompanied by transposition of the viscera. The aorta occasionally divides, as in some quadrupeds, into an ascending and a descending trunk, the former of which is directed vertically upwards, and subdivides into three branches, to supply the head and upper extremities. Sometimes the aorta subdivides near its origin into two branches, which soon reunite; in one case of this kind the œsophagus and trachea passed through the interval between the two branches; this is the normal condition of the vessel in the reptilia.

Applied Anatomy.—The ascending aorta and the arch of the aorta are frequent sites of aneurysm.

Aneurysm of the ascending aorta, in a majority of cases affects the anterior sinus, owing to the fact that the regurgitation of blood which follows the closing of the aortic valves is directed chiefly against the anterior wall of the vessel. If the aneurysmal sac projects forwards it may destroy part of the sternum and the costal cartilages, usually on the right side, and appear as a pulsating tumour on the front of the chest. In other cases it may compress or open into the right lung, bronchi, or trachea; it may burst into the pericardium (a common cause of death in these aneurysms), or may compress the right atrium, the pulmonary artery and the adjoining part of the right ventricle, and open into one or other of these structures. It may press upon the superior vena cava or the innominate veins, causing great venous engorgement in their tributaries; an aneurysm has occasionally perforated into the superior vena cava setting up an arteriovenous aneurysm.

Regarding the arch of the aorta, the student is reminded that the vessel lies against the trachea, left bronchus, œsophagus, and thoracic duct; that the recurrent nerve winds around it; and that from its upper part are given off three large trunks, which supply the head, neck, and upper extremities. An aneurysmal tumour taking origin from the posterior part of the vessel, its most usual site, may press upon the trachea and give rise to the sign known as 'tracheal tugging,' impede the breathing, or produce cough, dyspnœa, bronchiectasis, hæmoptysis, or stridulous breathing, or it may ultimately burst into that tube, producing fatal hæmorrhage. Again, its pressure on the left recurrent nerve may give rise to symptoms of laryngeal paralysis; or it may press upon the thoracic duct and destroy life by inanition; or it may involve the œsophagus, producing dysphagia, and has not infrequently been mistaken for œsophageal stricture; or it may burst into the œsophagus, when fatal hæmorrhage will occur. Pressure on the sympathetic filaments may produce (1) dilatation of the pupil by stimulation, or later (2) contraction of the pupil by abolition of the conducting power of the nerves, on the affected side. The pupillary changes have however been attributed to the alterations of the blood-pressure in the carotid artery on the affected side—lowering of pressure leading to partial collapse of the tortuous vessels of the iris and dilatation of the pupil, increase of pressure tending to straighten out these vessels and diminish the pupillary aperture. Again, the innominate artery, or

the subclavian, or left carotid, may be so obstructed by clots as to produce a weakness, or even a disappearance, of the pulse in one or the other wrist, or in the left superficial temporal artery; or the tumour may present itself at or above the manubrium, generally either in the median line, or to the right of the sternum, and may simulate an aneurysm of one of the arteries of the neck.

Many of the physical signs of an aortic aneurysm may be simulated with extraordinary fidelity by the preternatural pulsation or throbbing of a distended and elastic aorta, when no true aneurysmal dilatation exists. This condition may be met with in young persons with aortic reflux and greatly hypertrophied hearts, in patients who are of a neurotic or hysterical temperament, and in cases of Graves's disease or of marked anæmia. The condition is known as dynamic dilatation of the aorta, and in no way threatens life.

Branches (figs. 655, 658).—Three branches are given off from the summit of the arch of the aorta, viz.: the innominate, the left common carotid, and the left subclavian.

Peculiarities.—The branches may spring from the commencement of the arch or upper part of the ascending aorta; or the distance between them at their origins may be increased or diminished, the most frequent change in this respect being the approximation of the left carotid to the innominate artery.

The number of the primary branches may be reduced to one; more commonly there are two, the left carotid arising from the innominate artery, or (more rarely) the carotid and subclavian arteries of the left side arising from a left innominate artery. But the number may be increased to four, through the right carotid and subclavian arteries arising directly from the aorta; in most of these cases the right subclavian arises from the left end of the arch; in other cases it is the second or third branch given off. Another common variation in which there are four primary branches is that where the left vertebral artery arises from the arch of the aorta between the left carotid and subclavian arteries. Lastly, the number of trunks may be increased to five or six; in these instances, the external and internal carotid arteries arise separately, the common carotid being absent on one or both sides. In some few cases six branches have been found, and this condition is associated with the origin of both vertebral arteries from the arch.

When the aorta arches over to the right side, the three branches have an arrangement the reverse of what is usual: there is a left innominate artery, and the right carotid and right subclavian arise separately. In other cases, where the aorta takes its usual course, the two carotids may be joined in a common trunk, and the subclavians arise separately from the arch, the right subclavian generally arising from the left end of the arch.

Other arteries may spring from the arch of the aorta. Of these the most common are the bronchial, one or both, and the thyreoidea ima; the internal mammary and the inferior thyreoid have been seen to arise from it.

The Innominate Artery (figs. 655, 658, 659)

The **innominate artery** (arteria anonyma) is the largest branch of the arch of the aorta, and is from 4 to 5 cm. in length. It arises from the convexity of the arch of the aorta, posterior to the centre of the manubrium sterni; it passes obliquely upwards, backwards, and to the right to the level of the upper border of the right sternoclavicular articulation, where it divides into the right common carotid and right subclavian arteries.

Relations.—*Anteriorly*, it is separated from the manubrium sterni by the Sternohyoideus and Sternothyreoideus, the remains of the thymus, the left innominate and right inferior thyreoid veins which cross its root, and sometimes the superior cardiac branches of the right vagus nerve. *Posterior* to it is the trachea, which it crosses obliquely. On the *right side* are the right innominate vein, the upper part of the superior vena cava, and the pleura; and on the *left side*, the remains of the thymus, the origin of the left common carotid artery, the inferior thyreoid veins, and at a higher level the trachea.

Branches.—The innominate artery is usually devoid of branches other than its terminal ones, but occasionally the *thyreoidea ima* arises from it, and sometimes it gives off a *thymic* or a *bronchial branch*.

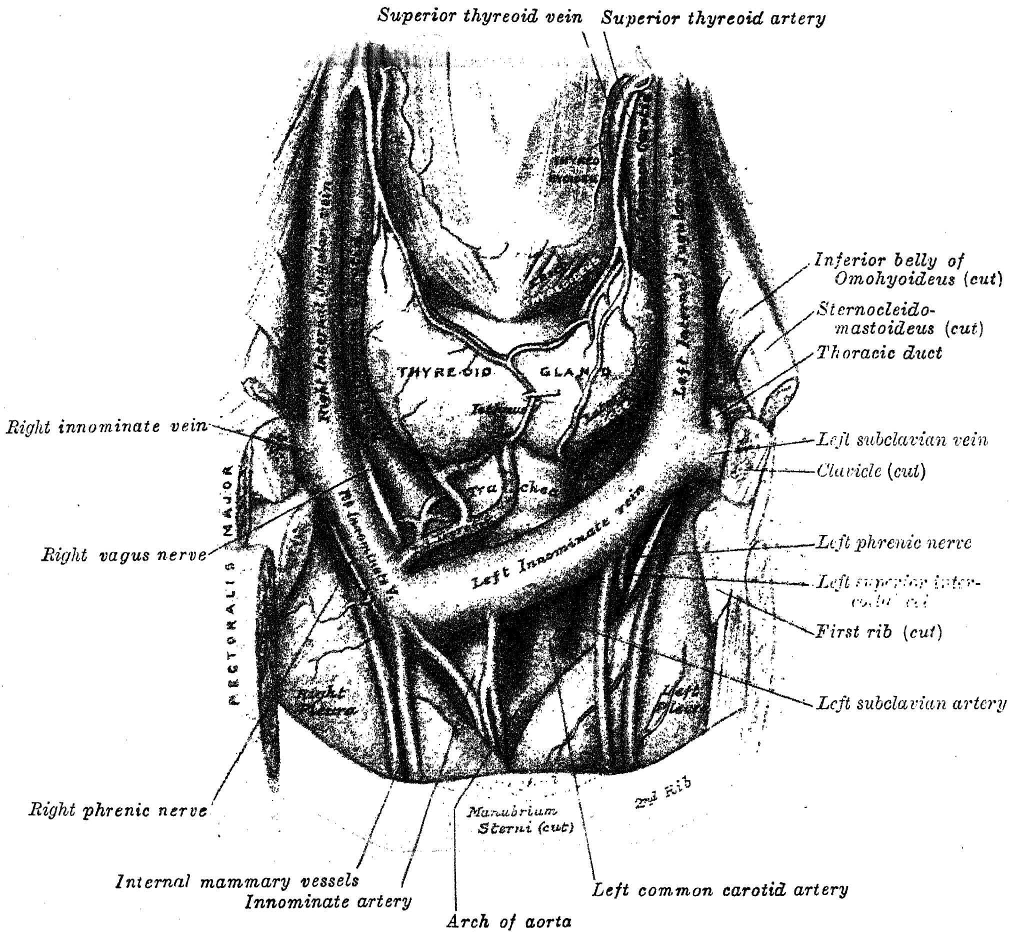
The **thyreoidea ima**, small and inconstant, ascends in front of the trachea to the lower part of the thyreoid gland, in which it ends. It occasionally arises from the aorta, or from the right common carotid, subclavian or internal mammary arteries.

Peculiarities.—The innominate artery sometimes projects above the upper border of the manubrium sterni. It may divide above the level of the sternoclavicular joint, less

frequently below it. When the aortic arch is on the right side, the innominate artery is directed to the left side of the neck.

Applied Anatomy.—The innominate artery may be wounded in performing the low operation of tracheotomy, and an ill-fitting tracheotomy tube may ulcerate into the vessel. Aneurysm of the innominate artery not infrequently occurs as an accompaniment of aneurysm of the arch of the aorta. It causes bulging of the right sternoclavicular articulation, pushing forwards the Sternocleidomastoideus muscle and filling up the jugular notch. It produces serious pressure symptoms: from pressure on the innominate veins it may cause œdema of the upper extremities, and of the head and neck; from pressure

Fig. 658.—Dissection of the lower part of the neck, and the upper part of the thorax. Anterior aspect.



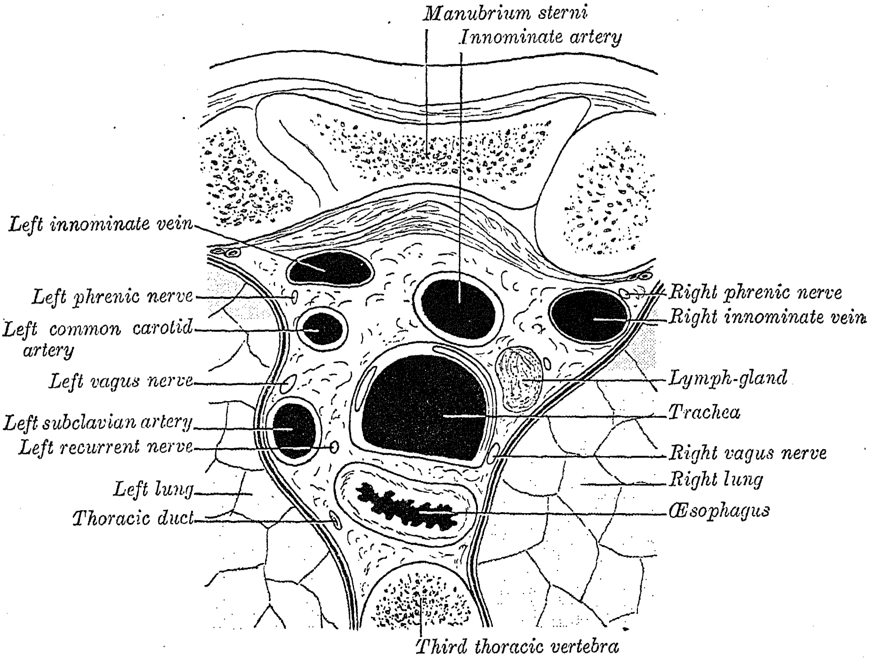
on the trachea it produces dyspnœa; and from pressure on the right recurrent nerve, hoarseness and laryngeal cough.

Although the operation of tying the innominate artery has been performed by several surgeons, few successes have been recorded. The chief danger of the operation appears to be the frequency of secondary hæmorrhage; but in the present day, with the practice of aseptic surgery and our greater knowledge of the use of the ligature, more favourable results may be anticipated. The main obstacles to the operation are the deep situation of the artery behind the sternum and the number of important structures which surround it.

In order to apply a ligature to this vessel, the patient is to be placed upon his back with the thorax slightly raised, the head bent a little backwards, and the right shoulder strongly depressed, so as to draw out the artery from behind the sternum into the neck. An incision 7 cm. or more in length is then made along the anterior border of the Sternocleidomastoideus, terminating at the sternal end of the clavicle. From this point, a second incision is carried about the same length along the upper border of the clavicle.

The skin is then dissected back, and the Platysma divided : the sternal end of the Sternocleidomastoideus is now brought into view, and a director being passed beneath it, and close to its deep surface so as to avoid any small vessels, it is to be divided; in like manner the clavicular origin is to be divided throughout the whole or greater part of its attachment. By pressing aside any loose cellular tissue or vessels that may now appear, the Sternohyoideus and Sternothyreoideus muscles will be exposed, and must be divided. The inferior thyreoid veins may come into view, and must be carefully drawn either upwards or downwards, by means of a blunt hook, or tied with double ligatures and divided. After tearing through a strong fibrocellular lamina, the right common carotid is brought into view, and being traced downwards, the innominate artery is reached. The left innominate vein should now be depressed; the right innominate vein, the internal

FIG. 659.—A transverse section through the mediastinal cavity at the level of the body of the third thoracic vertebra.



jugular vein, and the vagus nerve drawn to the right side ; and a curved aneurysm needle may then be passed around the vessel, close to its surface, and in a direction from below upwards and medially ; care being taken to avoid the right pleural sac, the trachea, and cardiac nerves. The ligature should be applied to the artery as high as possible, in order to allow room between it and the aorta for the formation of the coagulum. The importance of avoiding the thyreoid plexus of veins during the primary steps of the operation, and the pleural sac while including the vessel in the ligature, should be most carefully borne in mind. To give freer access to the innominate artery a portion of the manubrium sterni is sometimes removed.

Collateral Circulation.—Allan Burns demonstrated, on the dead subject, the possibility of the establishment of the collateral circulation after ligature of the innominate artery, by tying and dividing that artery. He then found that ' Even coarse injection, impelled into the aorta, passed freely by the anastomosing branches into the arteries of the right arm, filling them and all the vessels of the head completely.' * The branches by which this circulation is carried on are numerous; thus, all the communications across the middle line between the branches of the carotid arteries of opposite sides are available for the supply of blood to the right side of the head and neck; the anastomosis between the costocervical of the subclavian and the first aortic intercostal (see *infra* on the collateral circulation after obliteration of the thoracic aorta) brings the blood, by a free and direct course, into the right subclavian; the numerous connexions between the intercostal arteries and the branches of the axillary and internal mammary arteries assist in the supply of blood to the right arm, while the inferior epigastric from the external iliac, by means of its anastomosis with the internal mammary, compensates for any deficiency in the vascularity of the wall of the chest.

* *Surgical Anatomy of the Head and Neck*, p. 62.

THE ARTERIES OF THE HEAD AND NECK

The principal arteries of the head and neck are the two common carotids; they ascend in the neck and each divides into two branches, viz. (1) the external carotid, supplying the exterior of the head, the face, and the greater part of the neck; (2) the internal carotid, supplying to a great extent the parts within the cranial and orbital cavities.

The Common Carotid Arteries

The **common carotid arteries** differ in length and in their mode of origin. The *right* artery begins at the bifurcation of the innominate artery behind the sternoclavicular joint and is confined to the neck. The *left* artery springs from the highest part of the arch of the aorta immediately behind and to the left of the innominate artery, and therefore consists of a thoracic and a cervical portion.

The **thoracic portion of the left common carotid artery** (figs. 658, 659) ascends from the arch of the aorta to the level of the left sternoclavicular joint, where it is continuous with the cervical portion.

Relations.—*In front*, it is separated from the manubrium sterni by the Sternohyoideus and Sternothyreoideus, the anterior portions of the left pleura and lung, the left innominate vein, and the remains of the thymus; *behind* it are the left subclavian artery, the trachea, the œsophagus, the left recurrent nerve, and the thoracic duct. To its *right side* below, is the innominate artery, and above, the trachea, the inferior thyreoid veins, and the remains of the thymus; to its *left side* are the left vagus and phrenic nerves, the left pleura and lung.

The **cervical portions** of the common carotid arteries resemble each other so closely that one description will apply to both (figs. 660, 661). Each passes obliquely upwards, from behind the sternoclavicular articulation, to the level of the upper border of the thyreoid cartilage, where it divides into the external and internal carotid arteries; behind the point of division there is a small reddish brown, ductless gland, named the *glomus caroticum* (carotid body).

At the lower part of the neck the two arteries are separated from each other by a narrow interval which contains the trachea; but at the upper part, the thyreoid gland, the larynx, and the pharynx project forwards between the two vessels. The common carotid artery is contained in a sheath, which is derived from the fascia colli (deep cervical fascia) and encloses also the internal jugular vein and vagus nerve, the vein lying lateral to the artery, and the nerve between the artery and vein, on a plane posterior to both. In the sheath, each of these structures has a separate fibrous investment.

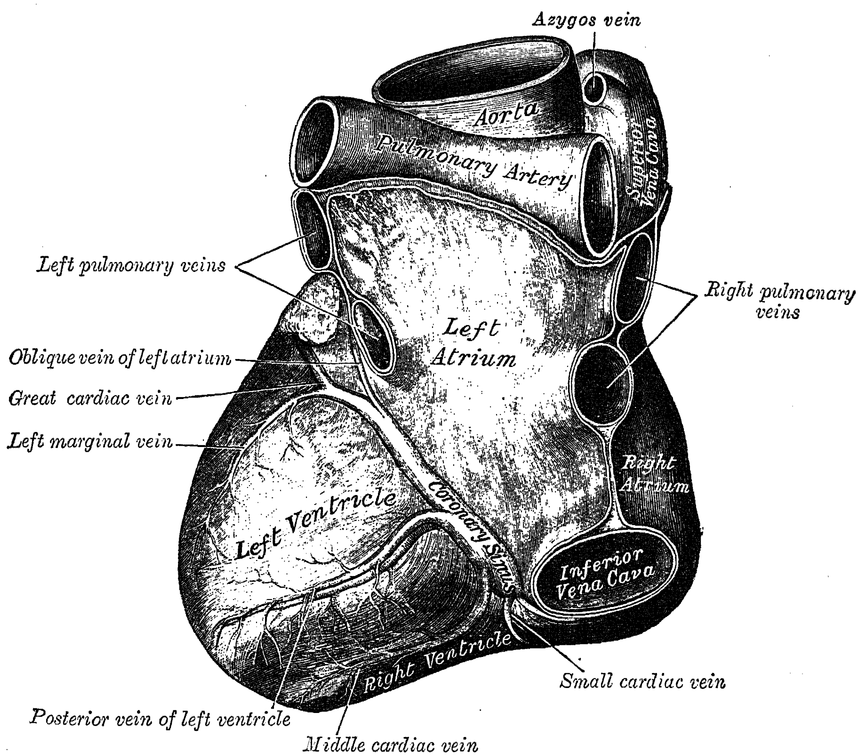
Relations.—In the lower part of its course the common carotid artery is very deeply seated, there being *in front* of it the skin, superficial fascia, Platysma, deep cervical fascia, Sternocleidomastoideus, Sternohyoideus, Sternothyreoideus, and Omohyoideus; in the upper part of its course it is more superficial, being covered merely by the skin, the superficial fascia, Platysma, deep cervical fascia, and the medial margin of the Sternocleidomastoideus. When the latter muscle is drawn backwards, the artery is seen to be contained in the *carotid triangle* (p. 621); this part of the artery is crossed obliquely, from its medial to its lateral side, by the sternocleidomastoid branch of the superior thyreoid artery. In front of or within its sheath is the descending branch of the hypoglossal nerve, this branch being joined by the descendens cervicalis nerve which springs from the second and third cervical nerves and crosses the vessel obliquely. The superior thyreoid vein crosses the artery near its termination, and the middle thyreoid vein a little below the level of the cricoid cartilage: the anterior jugular vein crosses the artery just above the clavicle, but is separated from it by the Sternohyoideus and Sternothyreoideus. *Behind*, the artery is separated from the transverse processes of the cervical vertebræ by the Longus colli and Longus capitis, the sympathetic trunk being interposed between the artery and the muscles; the inferior thyreoid artery crosses behind the lower part of the vessel. *Medial* to it are the œsophagus, trachea, and thyreoid gland (which overlaps it), the inferior thyreoid artery and recurrent nerve being

cava opens into the upper part, and the inferior vena cava into the lower part, of the right atrium. The portion of the left atrium between the openings of the right and left pulmonary veins constitutes the anterior wall of the oblique sinus of the pericardium (p. 576).

The *apex*, formed by the left ventricle, is directed downwards, forwards, and to the left, and is overlapped by the left lung and pleura: it lies behind the fifth left intercostal space, about 8 cm. from the mid-sternal line, or, in the male, about 4 cm. below and 2 cm. to the medial side of the left mammary papilla.

The *sternocostal surface* (fig. 638) is directed forwards, upwards, and to the left. It consists of an atrial and a ventricular portion, the former being above and to the right, the latter below and to the left, of the anterior part

FIG. 637.—The base and the diaphragmatic surface of the heart.



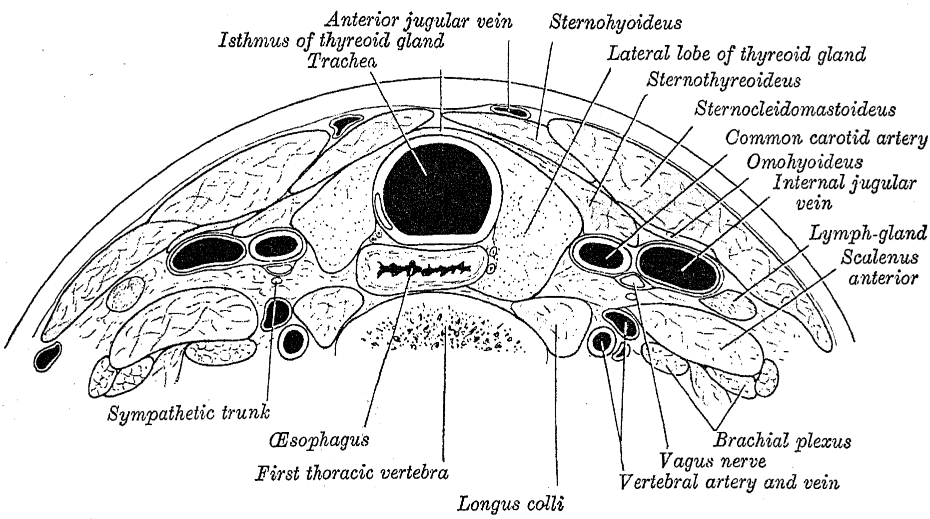
of the coronary sulcus. The atrial portion is almost entirely formed by the right atrium; the greater part of the left atrium is hidden by the ascending aorta and pulmonary artery (fig. 638), and only a small part of its auricula projects forwards on the left side of the pulmonary artery. About two-thirds of the ventricular part are formed by the right, and one-third by the left, ventricle, the line of separation between the ventricles being marked by the anterior longitudinal sulcus. The sternocostal surface lies behind the body of the sternum, the Transversus thoracis muscles and the cartilages of the third, fourth, fifth, and sixth ribs; owing to the bulging of the heart towards the left side a much larger part of the surface lies behind the left than the right rib-cartilages. The sternocostal surface is also covered by the pleuræ and the thin, anterior parts of the lungs, with the exception of a small triangular area corresponding with the cardiac notch in the left lung. The base of this area is represented by a line on the middle of the sternum from the level of the fourth costal cartilages to the junction of the body of the sternum with the xiphoid process, and the sides by lines from the apex of the heart to the upper and lower ends of the base line.

Division of the common carotid artery may occur at or about the level of the hyoid bone; more rarely it occurs below the usual level, opposite the middle of the larynx, or the lower border of the cricoid cartilage; one case is described by Morgagni, where the artery was only 4 cm. in length and divided at the root of the neck. Very rarely the artery ascends in the neck without undergoing subdivision, either the external or the internal carotid being wanting. In a few cases the artery has been found absent, the external and internal carotid arteries arising directly from the arch of the aorta; this peculiarity existed on both sides in some instances, on one side only in others.

The common carotid artery usually supplies no branch; but it may give origin to the vertebral, the superior thyreoid or its laryngeal branch, the ascending pharyngeal, the inferior thyreoid, or the occipital.

Applied Anatomy.—Aneurysms are not often found on the common carotid artery; when they do occur they are usually situated low down at the root of the neck, or just below the point of bifurcation of the vessel. They do not often assume a large size, and are more commonly found on the right side. As they increase in size they displace the trachea and larynx, and therefore dyspnœa becomes a prominent symptom. Dysphagia

FIG. 661.—A transverse section through the anterior part of the neck at the level of the body of the first thoracic vertebra.



also may be present from pressure on the œsophagus, especially if the aneurysm is on the left side; and pressure on the recurrent nerve may produce hoarseness and laryngeal cough. Pressure on the sympathetic will cause pupillary changes—dilatation of the pupil when the sympathetic is irritated or the arterial blood-supply to the eye is lessened, contraction when the sympathetic has become paralysed; sympathetic irritation may also cause unilateral sweating of the head and neck. Pressure on the superficial branches of the cervical plexus may give rise to pain in the head, face and neck; pressure on the vagus to irregular action of the heart and to asthmatic attacks. It is important to bear in mind that an enlarged lymph-gland in the superior carotid triangle, receiving a transmitted pulsation from the carotid artery, may simulate aneurysm of that vessel, but may be distinguished from it by the character of the pulsation, which is not expansile.

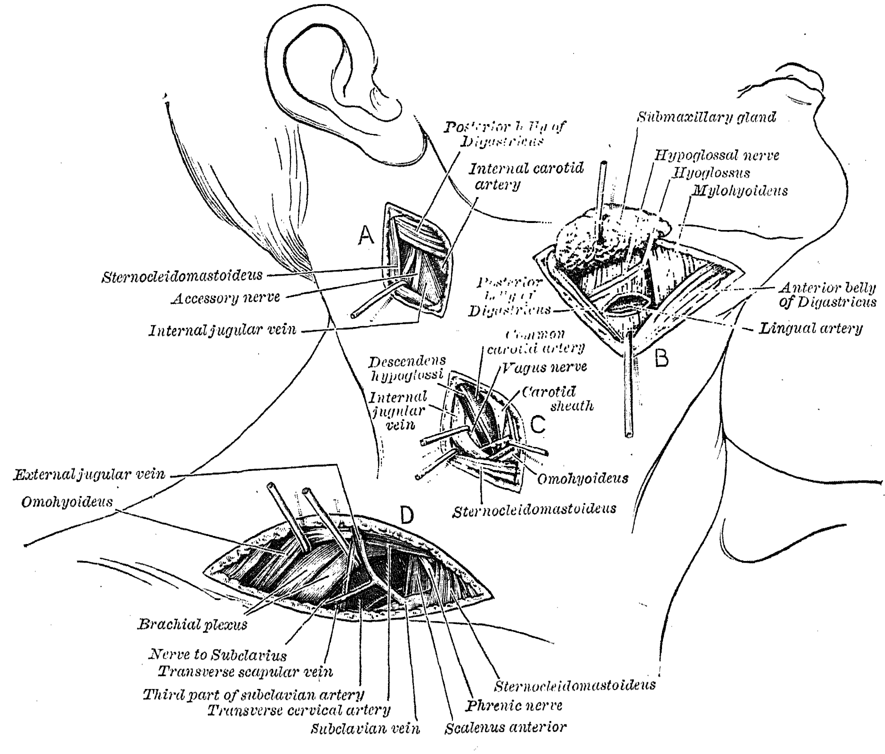
Embolism of the left common carotid artery, or the thrombosis that may follow injury to the wall of the vessel by penetrating gunshot wounds of the neck, have been known to produce aphasia by interference with the blood-supply of the brain.

Digital compression of the common carotid artery is sometimes required, and is best effected by pressing the vessel with the thumb against the anterior tubercle of the transverse process of the sixth cervical vertebra (p. 167).

The upper part of the common carotid artery should be selected as the spot upon which to place a ligature (fig. 662 c), for the lower part is placed very deeply; moreover, on the left side, the internal jugular vein, in most cases, passes obliquely in front of it. The part of the vessel which is most favourable for the operation is that opposite the level of the cricoid cartilage. It occasionally happens that the artery divides below its usual position: if the artery be exposed at its point of bifurcation, both divisions of the vessel should be tied near their origin, in preference to tying the trunk of the artery near its termination; and if, in consequence of the entire absence of the common carotid artery, or from its early division, two arteries, the external and internal carotids, are met with, the ligature should be placed on that vessel which is found on compression to be connected with the diseased area.

In this operation, the direction of the vessel and the anterior margin of the Sternocleidomastoideus are the chief guides to its performance. The patient should be placed on his back with the head extended and turned slightly to the opposite side: an incision is to be made, 7 or 8 cm. long, in the direction of the anterior border of the Sternocleidomastoideus, so that the centre corresponds to the level of the cricoid cartilage. After dividing the integument, superficial fascia, Platysma, and deep fascia, the margins of the wound are held asunder by retractors, and the ramus descendens hypoglossi exposed, and must be avoided. The sheath of the vessel is to be raised by forceps, and opened to a small extent over the artery at its medial side. The internal jugular vein may present itself alternately distended and relaxed, and must be carefully avoided. The aneurysm needle is passed from the lateral aspect, care being taken to keep the needle in close contact with the artery, and thus avoid the risk of injuring the internal jugular vein, or including the vagus nerve. Before the ligature is tied, it should be ascertained that nothing but the artery is included in it.

FIG. 662.—Dissections to show (A) the accessory nerve, (B) the lingual artery, (C) the common carotid artery, and (D) the third part of the subclavian artery.



Ligature of the common carotid near the root of the neck is sometimes required in cases of aneurysm of the upper part of the artery, especially if the sac is of large size. It is best performed by dividing the sternal origin of the Sternocleidomastoideus, but may be done in some cases, if the aneurysm is not of very large size, by an incision along the anterior border of the muscle, extending down to the sternoclavicular articulation, and by then retracting the muscle. Beneath it are two additional muscular layers, viz.: the Sternohyoideus and the Sternothyreoideus: these have to be split and retracted, one after the other, before the sheath of the vessel is reached. In doing this, care must be taken not to wound the anterior jugular vein, which crosses the Sternohyoideus to reach the external jugular or subclavian vein. The sheath must be opened on its medial or tracheal side, so as to avoid the internal jugular vein. Special care is necessary on the left side, where the artery is commonly overlapped by the vein; on the right side there is usually an interval between the artery and the vein, and the risk of wounding the latter is less.

Brasdor's method of ligaturing an artery on the distal side of an aneurysm is particularly suitable for the cure of aneurysm at the lower part of the common carotid artery, since no branches are given off from the artery between the aneurysm and the site of the ligature.

Collateral Circulation.—After ligature of the common carotid, the collateral circulation can be perfectly established by the free communication which exists between the carotid arteries of opposite sides, both without and within the cranium, and by enlargement of the branches of the subclavian artery. The chief communications outside the skull take place between the superior and inferior thyreoid arteries, and between the profunda cervicis and ramus descendens of the occipital; the vertebral takes the place of the internal carotid within the cranium.

Wounds of the common carotid should be treated by suture whenever possible, because, after ligature of the vessel, hemiplegia or other symptom of cerebral disturbance supervenes in about twenty-five per cent. of cases.

The External Carotid Artery

The **external carotid artery** (fig. 660) begins opposite the upper border of the thyreoid cartilage, at the level of the disc between the third and fourth cervical vertebræ, and, taking a slightly curved course, passes upwards and forwards, and then inclines backwards to a point behind the neck of the mandible, where it divides into the superficial temporal and internal maxillary arteries. It diminishes rapidly in size, owing to the number and large size of the branches given off from it. In the child, it is somewhat smaller than the internal carotid; but in the adult, the two vessels are of nearly equal size. At its origin, this artery is more superficial, and placed nearer the middle line than the internal carotid artery, and is contained within the carotid triangle.

Relations.—The external carotid artery is *covered by* the skin, superficial fascia, Platysma, deep fascia, and anterior margin of the Sternocleidomastoideus; it is crossed by the Digastricus and Stylohyoideus, the hypoglossal nerve and its vena comitans, the lingual and the common facial veins, and sometimes by the superior thyreoid veins, higher up it passes into the substance of the parotid gland, where it lies deep to the facial nerve and the junction of the superficial temporal and internal maxillary veins. *Medial* to it are the hyoid bone, the wall of the pharynx, the superior laryngeal nerve, and a portion of the parotid gland. *Lateral* to it, in the lower part of its course, is the internal carotid artery. Higher up it is separated from the internal carotid artery by the styloid process or stylohyoid ligament, the Styloglossus and Stylopharyngeus muscles, the glossopharyngeal nerve, the pharyngeal branch of the vagus nerve, and part of the parotid gland.

Applied Anatomy.—Ligature of the external carotid may be required in cases of wound of this vessel, or of its branches when these cannot be tied, and in some cases of pulsating tumours of the scalp or face. It is also done as a preliminary measure to excision of the maxilla or tonsil. The seat of election for ligature is between the origins of its superior thyreoid and lingual branches, about a finger's breadth below the tip of the greater cornu of the hyoid bone. To tie the vessel, an incision is made from the angle of the mandible to the upper border of the thyreoid cartilage, and the superficial tissues and the deep fascia divided. The anterior border of the Sternocleidomastoideus must be retracted and the lower border of the parotid gland raised, so as to expose the tendon of the Digastricus and the hypoglossal nerve, which cross the artery. The great difficulty in doing this is due to the plexus of veins derived from the superior thyreoid and lingual veins, which overlie the artery; if necessary, these must be ligatured and divided. Care must be taken not to mistake the lingual and external maxillary arteries, when they arise by a common trunk, as they sometimes do, for the external carotid artery. The needle is to be passed from the lateral to the medial side of the vessel, carefully avoiding the superior laryngeal nerve, which lies in close proximity to the artery.

Collateral Circulation.—The circulation is re-established by the free communication between most of the large branches of the artery (external maxillary, lingual, superior thyreoid, occipital) and the corresponding arteries of the opposite side, and by the anastomosis of its branches with those of the internal carotid artery, and of the occipital artery with branches of the subclavian, &c.

The Branches of the External Carotid Artery (figs. 660, 663)

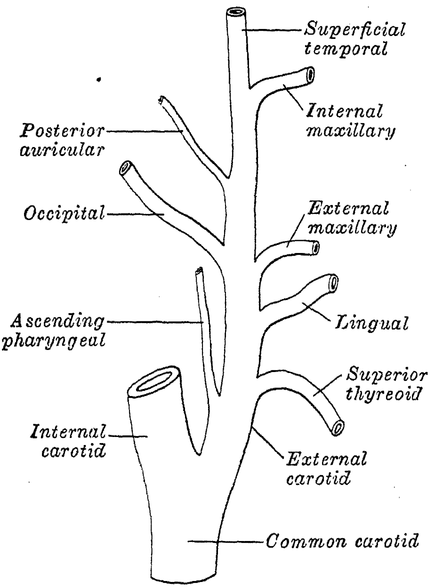
The branches of the external carotid artery are:

1. Superior thyreoid.
2. Ascending pharyngeal.
3. Lingual.
4. External maxillary.
5. Occipital.
6. Posterior auricular.
7. Superficial temporal.
8. Internal maxillary.

1. The **superior thyreoid artery** (fig. 660) arises from the external carotid artery just below the level of the greater cornu of the hyoid bone and ends in the thyreoid gland.

Relations.—From its origin beneath the anterior border of the Sternocleidomastoideus it runs upwards and forwards for a short distance in the carotid triangle, where it is covered by the skin, Platysma, and fascia; it then arches downwards beneath the Omohyoideus, Sternohyoideus, and Sternothyreoideus. To its medial side are the Constrictor pharyngis inferior and the external branch of the superior laryngeal nerve.

FIG. 663.—Plan of the branches of the external carotid artery.



Branches.—It distributes twigs to the adjacent muscles, and branches to the thyreoid gland; it anastomoses with its fellow of the opposite side, and with the inferior thyreoid arteries. The branches to the gland are generally two in number, an anterior and a posterior; the anterior and larger branch supplies principally the anterior surface; on the isthmus of the gland it anastomoses with the corresponding artery of the opposite side; the posterior branch descends on the posterior surface of the gland and anastomoses with the inferior thyreoid artery.

Besides the arteries distributed to the muscles and to the thyreoid gland, the superior thyreoid artery supplies the following branches:

Hyoid.
Sternocleidomastoid.
Superior laryngeal.
Cricothyreoid.

The **hyoid branch** is small and runs along the lower border of the hyoid bone beneath the Thyreohyoideus, and anastomoses with the vessel of the opposite side.

The **sternocleidomastoid branch** frequently arises from the external carotid artery; it runs downwards and lateralwards across the sheath of the common carotid artery, and enters the Sternocleidomastoideus.

The **superior laryngeal artery**, larger than either of the preceding, is also frequently a separate branch of the external carotid artery; it accompanies the internal laryngeal branch of the superior laryngeal nerve, beneath the Thyreohyoideus; it pierces the lower part of the hyothyreoid membrane, and supplies the muscles, mucous membrane and glands of the larynx, anastomosing with the artery of the opposite side, and with the inferior laryngeal branch of the inferior thyreoid artery.

The **cricothyreoid branch** is small and runs transversely across the upper part of the cricothyreoid membrane, communicating with the artery of the opposite side.

Applied Anatomy.—The superior thyreoid artery, or one of its branches, is often divided in cases of cut throat, giving rise to considerable hæmorrhage. The superior thyreoid is ligatured in cases of bronchocele where the removal of a lobe of the thyreoid gland may present special dangers.

The position of the sternocleidomastoid branch is of importance in connexion with the operation of ligature of the common carotid artery. It crosses and lies on the sheath of this vessel and may chance to be wounded in opening the sheath. The position of the cricothyreoid branch should be remembered, as it may prove the source of troublesome hæmorrhage during the operation of laryngotomy.

2. The **ascending pharyngeal artery** (fig. 668), the smallest branch of the external carotid artery, is a long, slender vessel, deeply seated in the neck. It arises close to the origin of the external carotid artery, and ascends vertically between the internal carotid artery and the side of the pharynx to the under surface of the base of the skull, lying on the Longus capitis; it anastomoses freely with the ascending palatine branch of the external maxillary artery.

Its branches are:

Pharyngeal. Inferior tympanic. Posterior meningeal.

The **pharyngeal branches** are three or four in number. Two of these descend to supply the Constrictores pharyngis medius et inferior and the Stylopharyngeus, ramifying in their substance and in the underlying mucous membrane. A branch of variable size is distributed to the palate, and may take the place of the ascending palatine branch of the external maxillary artery; it runs downwards and forwards between the superior border of the Constrictor pharyngis superior and the Levator veli palatini, and accompanies the latter muscle to the soft palate; it gives branches to the tonsil, and supplies a twig to the auditory tube.

The **inferior tympanic artery** is a small branch which passes through the inferior tympanic canaliculus of the temporal bone, in company with the tympanic branch of the glossopharyngeal nerve, to supply the medial wall of the tympanic cavity and anastomose with the other tympanic arteries.

The **meningeal branches** are several small vessels which supply the dura mater. One, the *posterior meningeal*, enters the cranium through the foramen lacerum; a second passes through the jugular foramen; and occasionally a third through the canal for the hypoglossal nerve.

Numerous small vessels supply the Longi capitis et colli, the sympathetic trunk, the hypoglossal and vagus nerves, and the lymph-glands; they anastomose with the ascending cervical and vertebral arteries.

3. The **lingual artery** (fig. 668) arises from the external carotid artery between the superior thyreoid and external maxillary arteries; it runs obliquely upwards and medialwards to the greater cornu of the hyoid bone, and then curves downwards and forwards, forming a loop which is crossed by the hypoglossal nerve; it passes beneath the Digastricus and Stylohyoideus, runs horizontally forwards beneath the Hyoglossus, and finally, ascending almost perpendicularly to the tongue, courses forwards on its lower surface as far as the tip.

Relations.—Its first portion is contained within the carotid triangle; it rests upon the Constrictor pharyngis medius, and is under cover of the Platysma and the fascia of the neck. Its second portion also lies upon the Constrictor pharyngis medius, being at first under cover of the tendon of the Digastricus and the Stylohyoideus, and afterwards of the Hyoglossus. Its third portion lies between the Hyoglossus and Genioglossus. The fourth or terminal part, under the name of the *arteria profunda linguæ* (ranine artery), runs along the inferior surface of the tongue to its tip, covered only with the mucous membrane; above it is the Longitudinalis inferior, and medial to it the Genioglossus. The hypoglossal nerve crosses the first part of the lingual artery, but is separated from the second part by the Hyoglossus.

The branches of the lingual artery are:

Hyoid.	Sublingual.
Rami dorsales linguæ.	Arteria profunda linguæ.

The **hyoid branch** is very small; it runs along the upper border of the hyoid bone, supplying the muscles attached to the bone, and anastomosing with its fellow of the opposite side.

The **rami dorsales linguæ** consist usually of two or three small branches; they arise beneath the Hyoglossus, ascend to the posterior part of the dorsum of the tongue, and supply the mucous membrane of the tongue, the glossopalatine arch, the palatine tonsil, soft palate, and epiglottis; they anastomose with the vessels of the opposite side.

The **sublingual artery** arises at the anterior margin of the Hyoglossus, and runs forward between the Genioglossus and Mylohyoideus to the sublingual gland. It supplies the gland and gives branches to the Mylohyoideus and neighbouring muscles, and to the mucous membrane of the mouth and gums. One branch runs behind the alveolar part of the mandible in the substance of the gum to anastomose with a similar artery from the other side; another pierces the Mylohyoideus and anastomoses with the submental branch of the external maxillary artery.

The **arteria profunda linguæ** (ranine artery) is the terminal portion of the lingual artery; it pursues a tortuous course and runs along the under surface of the tongue at the side of the frenulum linguæ, between the Longitudinalis linguæ inferior and the mucous membrane; it lies on the lateral side of the Genioglossus, accompanied by the lingual nerve.

Applied Anatomy.—The lingual artery is not infrequently divided near its origin in cases of cut throat; while severe hæmorrhage, which cannot be restrained by ordinary means, may ensue from a wound, or deep ulcer, of the tongue. In the former case, the primary wound may be enlarged if necessary, and the bleeding vessel secured; in the latter, it has been suggested that the lingual artery should be tied near its origin.

Ligature of the lingual artery (fig. 662, B) has been practised as a preliminary measure to removal of the tongue. The operation is a difficult one on account of the depth of the artery, the number of important parts by which it is surrounded, and its occasional irregularity of origin. An incision is to be made in a curved direction from a finger's breadth behind the symphysis menti downwards to the cornu of the hyoid bone, and then upwards to near the angle of the mandible. Care must be taken not to carry this incision too far backwards, for fear of endangering the anterior facial vein. In the first incision the skin, superficial fascia, and Platysma will be divided, and the deep fascia displayed. This is then to be incised and the submaxillary gland exposed and pulled upwards. A triangular space is now seen, bounded in front by the posterior border of the Mylohyoideus, below and behind by the tendon of the Digastricus, and above by the hypoglossal nerve. The floor of the space is formed by the Hyoglossus, beneath which the artery lies. The parts are to be drawn forwards by a blunt hook inserted beneath the tendon of the Digastricus, and the fibres of the Hyoglossus cut through horizontally just above the Digastricus. The artery will then be exposed lying on the Constrictor pharyngis medius; and in passing the aneurysm needle, care must be taken not to pierce the latter muscle. The hypoglossal nerve must also be avoided.

Troublesome hæmorrhage may occur in the division of the frenulum linguæ in children, if the aa. profundæ linguæ, which lie one on either side of it, be wounded. The operation should always be performed with a pair of blunt-pointed scissors, and the mucous membrane alone divided by a very superficial cut, which cannot endanger any vessel. Any further liberation of the tongue which may be necessary can be effected by tearing.

4. The **external maxillary artery** (facial artery) (fig. 664) arises from the external carotid artery in the carotid triangle a little above the lingual artery. Sheltered by the ramus of the mandible, it passes obliquely up beneath the Digastricus and Stylohyoideus, above which it arches to enter a groove on the posterior border of the submaxillary gland. It then curves upwards over the body of the mandible at the antero-inferior angle of the Masseter; passes forwards and upwards across the cheek to the angle of the mouth, then ascends along the side of the nose, and ends as the *angular artery* at the medial palpebral commissure. The external maxillary artery is remarkably tortuous: in the neck to accommodate itself to the movements of the pharynx during deglutition, and on the face to the movements of the mandible, lips, and cheeks.

Relations.—*In the neck*, its origin is superficial, being placed under cover of the skin, Platysma, and fascia; it then passes beneath the Digastricus and Stylohyoideus muscles and part of the submaxillary gland, and frequently beneath the hypoglossal nerve. It lies upon the Constrictores pharyngis medius et superior, the latter of which separates it, at the summit of its arch, from the lower and posterior part of the tonsil. *On the face*, where it passes over the body of the mandible, it is comparatively superficial, lying immediately beneath the Platysma. In its course over the face, it is under cover of the skin, the fat of the cheek, and, near the angle of the mouth, the Platysma, Risorius, and Zygomaticus. It rests on the Buccinator and Caninus, and passes either over or through the infra-orbital head of the Quadratus labii superioris. The anterior facial vein lies posterior to the artery, and takes a more direct course across the face, where it is separated from the artery by a considerable interval; in the neck it lies superficial to the artery. The branches of the facial nerve cross the artery from behind forwards.

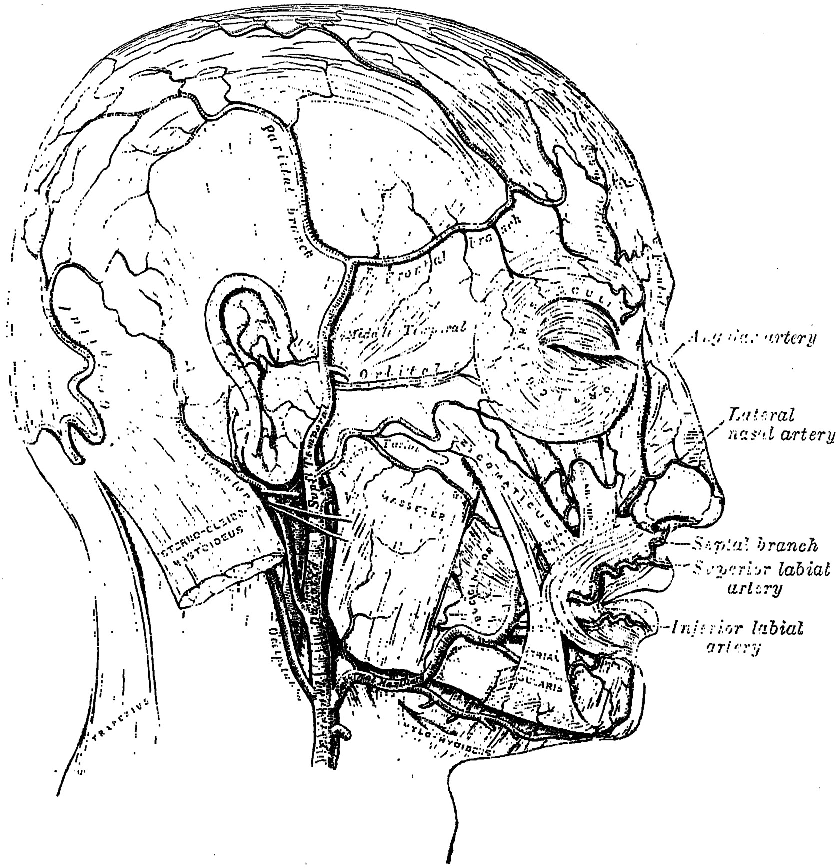
The branches of the external maxillary artery may be divided into two sets: those given off in the neck (cervical), and those on the face (facial).

Cervical branches.	*Facial branches.*
Ascending palatine.	Inferior labial.
Tonsillar.	Superior labial.
Glandular.	Lateral nasal.
Submental.	Angular.

The **ascending palatine artery** (fig. 668) arises close to the origin of the external maxillary artery and passes up between the Styloglossus and Stylopharyngeus to the side of the pharynx, along which it is continued between the Constrictor pharyngis superior and the Pterygoideus internus towards the base of the skull.

Near the Levator veli palatini it divides into two branches: one follows the course of this muscle, and, winding over the upper border of the Constrictor pharyngis superior, supplies the soft palate and the palatine glands, anastomosing with its fellow of the opposite side and with the descending palatine branch of the internal maxillary artery; the other pierces the Constrictor pharyngis superior and supplies the palatine tonsil and auditory tube, anastomosing with the tonsillar and ascending pharyngeal arteries.

FIG. 664.—The arteries of the right side of the face and scalp.



The **tonsillar branch** (fig. 668), sometimes derived from the ascending palatine artery, ascends between the Pterygoideus internus and Styloglossus, and then along the side of the pharynx; it perforates the Constrictor pharyngis superior and ramifies in the palatine tonsil and the root of the tongue.

The **glandular branches**, three or four large vessels, supply the submaxillary salivary gland and lymph-glands, the neighbouring muscles, and the skin.

The **submental artery**, the largest cervical branch of the external maxillary artery, springs from that artery just as it quits the submaxillary gland: it runs forwards upon the Mylohyoideus, below the body of the mandible, and beneath the anterior belly of the Digastricus. It supplies the surrounding muscles, and anastomoses with the sublingual artery and with the mylohyoid branch of the inferior alveolar artery; at the chin it turns upwards over the inferior border of the mandible and divides into a superficial and a deep branch. The superficial branch passes between the skin and the Quadratus labii inferioris, and anastomoses with the inferior labial artery; the deep branch runs between the muscle and the bone, supplies the lip, and anastomoses with the inferior labial and mental arteries.

The **inferior labial artery** (inferior coronary artery) arises near the angle of the mouth; it passes upwards and forwards beneath the Triangularis, and, penetrating the Orbicularis oris, runs in a tortuous course near the edge of the lower lip between this muscle and the mucous membrane. It supplies the glands, mucous membrane and muscles of the lower lip; and anastomoses with the artery of the opposite side, and with the mental branch of the inferior alveolar artery.

The **superior labial artery** (superior coronary artery) is larger and more tortuous than the inferior. It follows a similar course near the edge of the upper lip, lying between the mucous membrane and the Orbicularis oris, and anastomoses with the artery of the opposite side. It supplies the upper lip, and gives off a *septal branch* which ramifies on the lower and front part of the nasal septum, and an *alar branch* which supplies the ala of the nose.

The **lateral nasal branch** is derived from the external maxillary artery as that vessel ascends along the side of the nose. It supplies the ala and dorsum of the nose anastomosing with its fellow, with the septal and alar branches, with the dorsal nasal branch of the ophthalmic artery, and with the infra-orbital branch of the internal maxillary artery.

The **angular artery** is the terminal part of the external maxillary artery; it ascends to the medial angle of the eye, imbedded in the fibres of the angular head of the Quadratus labii superioris, and accompanied by the angular vein. On the cheek it anastomoses with the infra-orbital artery, and, after supplying the lacrimal sac and Orbicularis oculi, ends by anastomosing with the dorsal nasal branch of the ophthalmic artery.

The anastomoses of the external maxillary artery are very numerous, not only with the branches of the vessel of the opposite side, but, *in the neck*, with the sublingual branch of the lingual, with the ascending pharyngeal, and with the palatine branch of the internal maxillary; *on the face*, with the mental branch of the inferior alveolar, the transverse facial branch of the superficial temporal, the infra-orbital branch of the internal maxillary, and the dorsal nasal branch of the ophthalmic.

Peculiarities.—The external maxillary artery not infrequently arises in common with the lingual artery. It varies in size, and in the extent to which it supplies the face; it occasionally ends as the submental, and not infrequently extends only as high as the angle of the mouth or nose. The deficiency is then compensated for by enlargement of one of the neighbouring arteries.

Applied Anatomy.—The passage of the external maxillary artery over the body of the mandible would appear to afford a favourable position for the application of pressure in cases of hæmorrhage from the lips; but such application is useless, except for a very short time, on account of the free communication of the artery with its fellow, and with numerous branches from different sources. In a wound involving the lip, it is better to seize the part between the fingers, and evert it, when the bleeding vessel may be at once secured with pressure-forceps. In order to prevent hæmorrhage during the removal of growths from the lip, the latter should be compressed on either side between the fingers and thumb, or by a pair of specially devised clamp-forceps, while the surgeon excises the diseased part. In order to stop hæmorrhage when the lip has been divided in an operation, it is necessary, when closing the wound, to pass the sutures through the cut edges, almost as deep as its mucous surface, because the labial arteries run in the submucous layer of the lips; by these means, not only are the cut surfaces more neatly and securely adapted to each other, but the possibility of hæmorrhage is prevented by including the divided artery in the suture. If, on the contrary, the suture be passed through merely the cutaneous portion of the wound, hæmorrhage occurs into the cavity of the mouth. The student should observe that the angular artery ascends on the nasal side of the lacrimal sac; in operating for fistula lacrimalis, the sac should always be opened on its lateral side, in order to avoid this vessel.

The external maxillary artery is separated from the lower and hinder part of the tonsil by the Constrictor pharyngis superior, and may be wounded in operations in that region.

The free anastomosis of the branches of the external maxillary artery contributes to the success of plastic operations on the face.

5. The **occipital artery** (fig. 664) arises from the posterior part of the external carotid artery, opposite to the external maxillary artery, and near the lower margin of the posterior belly of the Digastricus; it ends in the posterior part of the scalp.

Relations.—At its origin, it is under cover of the posterior belly of the Digastricus and the Stylohyoideus, and the hypoglossal nerve winds round it from behind forwards; higher up, it crosses the internal carotid artery, the internal jugular vein, and the vagus and accessory nerves. It next ascends along the lower border of

which lies within the fibrous sac and lines its walls; it is composed of a single layer of flattened cells resting on loose connective tissue. The heart invaginates the wall of the serous sac from above and behind, and practically obliterates its cavity, the space being a potential one.

The *fibrous pericardium* forms a flask-shaped bag, the neck of which is closed by its continuity with the external coats of the great vessels, while its base is attached to the central tendon and to the muscular fibres of the left half of the Diaphragm. In some of the lower mammals the base is either completely separated from the Diaphragm or joined to it by some loose areolar tissue; in man much of its diaphragmatic attachment consists of loose fibrous tissue which can be readily broken down, but over a small area the central tendon of the Diaphragm and the pericardium are fused. Above, the fibrous pericardium not only blends with the external coats of the great vessels, but is continuous with the pretracheal layer of the fascia colli (deep cervical fascia). By means of these upper and lower connexions it is securely anchored within the thoracic cavity. It is also attached to the posterior surface of the sternum by a *superior* and an *inferior sternopericardial ligament*; the superior passing to the manubrium, and the inferior to the xiphoid process.

The vessels receiving prolongations from the fibrous pericardium are: the aorta, the superior vena cava, the right and left pulmonary arteries, and the four pulmonary veins. The inferior vena cava enters the pericardium through the central tendon of the Diaphragm, and receives no covering from the fibrous layer.

The *serous pericardium* is, as already stated, a closed sac which lines the fibrous pericardium and is invaginated by the heart; it therefore consists of a *visceral* and a *parietal* portion. The visceral portion, or *epicardium*, covers the heart and the great vessels, and from the latter is continuous with the parietal layer which lines the fibrous pericardium. The portion which covers the vessels is arranged in the form of two tubes. The aorta and pulmonary artery are enclosed in one tube, the *arterial mesocardium*. The superior and inferior venæ cavæ and the four pulmonary veins are enclosed in a second tube, the *venous mesocardium*, the attachment of which to the parietal layer is ∩-shaped. The cul-de-sac between the limbs of the ∩ lies behind the left atrium and is known as the *oblique sinus*, while the passage between the venous and arterial mesocardia—i.e. between the aorta and pulmonary artery in front and the atria behind—is termed the *transverse sinus*.

The ligament of the left vena cava.—Between the left pulmonary artery and subjacent pulmonary vein is a triangular fold of the serous pericardium, known as the *ligament of the left vena cava* (vestigial fold of Marshall). It is formed by the duplicature of the serous layer over the remnant of the lower part of the left duct of Cuvier (left superior vena cava) (p. 127). This vein becomes obliterated during fœtal life, and remains as a fibrous band stretching from the upper part of the left superior intercostal vein to the back of the left atrium, where it is continuous with a small vein, the *oblique vein of the left atrium* (oblique vein of Marshall), which opens into the coronary sinus (fig. 637).

The *arteries* of the pericardium are derived from the internal mammary arteries and their musculophrenic branches, and from the descending thoracic aorta; its *nerves* are derived from the vagus and phrenic nerves, and the sympathetic trunks.

Applied Anatomy.—Effusion of fluid into the pericardial sac often occurs in acute rheumatism or pneumonia, or in patients with chronic vascular and renal disease, embarrassing the heart's action and giving rise to signs of cardiac distress, such as pallor, a rapid and feeble pulse, dyspnœa, and restlessness. On examination, the apical cardiac impulse is absent, or replaced by a more extensive indefinite and wavering pulsation; it may appear to be in the second, third, or fourth left space, and is then not an apex-impulse, as Potain has stated, but due to the impact of some portion of the heart-wall nearer its base. In children the precordial intercostal spaces may bulge outwards. The most striking sign, however, is the great increase in all directions of the precordial dulness on percussion. This becomes pear-shaped, the stalk of the pear reaching up to about the left sternoclavicular articulation; the dulness also extends some distance to the right of the sternum, particularly in the fifth interspace (Rotch). The fluid collects mainly on either side of the heart, and below it, especially on the left side, where the Diaphragm can yield more readily to pressure than it can on the right. Ewart has drawn attention to the presence of a square patch of dulness over the base of the left lung behind, reaching up to

The **occipital branch** passes backwards over the Sternocleidomastoideus to the Occipitalis muscle and the scalp above and behind the ear; it anastomoses with the occipital artery.

7. The **superficial temporal artery** (fig. 664), the smaller terminal branch of the external carotid artery, begins in the parotid gland, behind the neck of the mandible, and crosses over the posterior root of the zygomatic process of the temporal bone; about 5 cm. above this process it divides into a frontal and a parietal branch.

Relations.—As it crosses the zygomatic process, it is covered by the Auricularis anterior; it is crossed by the temporal and zygomatic branches of the facial nerve and is accompanied by the auriculotemporal nerve, which lies immediately behind it.

It supplies some twigs to the parotid gland, the mandibular joint, and the Masseter, and gives off the following branches:

Transverse facial.	Zygomatico-orbital.	Frontal.
Anterior auricular.	Middle temporal.	Parietal.

The **transverse facial artery** (fig. 664) arises from the superficial temporal artery before that vessel quits the parotid gland; it runs forwards through the substance of the gland, passes across the Masseter between the parotid duct and the zygomatic arch, accompanied by one or two branches of the facial nerve. It divides into numerous branches which supply the parotid gland and duct, the Masseter, and the skin, and anastomose with the external maxillary, masseteric, buccinator, and infra-orbital arteries.

The **anterior auricular branches** are distributed to the lobule and anterior portion of the auricula, and to the external acoustic meatus; they anastomose with the posterior auricular artery.

The **zygomatico-orbital artery,** sometimes a branch of the middle temporal artery, runs along the upper border of the zygomatic arch between the two layers of the temporal fascia to the lateral angle of the orbit. It supplies branches to the Orbicularis oculi, and anastomoses with the lacrimal and palpebral branches of the ophthalmic artery.

The **middle temporal artery** arises immediately above the zygomatic arch, and, perforating the temporal fascia, gives branches to the Temporalis; it anastomoses with the deep temporal branches of the internal maxillary artery.

The **frontal branch** runs tortuously upwards and forwards towards the frontal tuberosity; it supplies the muscles, skin, and pericranium in this region, and anastomoses with its fellow of the opposite side, and with the supra-orbital and frontal arteries.

The **parietal branch,** larger than the frontal, curves upwards and backwards on the side of the head, lying superficial to the temporal fascia, and anastomosing with its fellow of the opposite side, and with the posterior auricular and occipital arteries.

Applied Anatomy.—As the superficial temporal artery crosses the zygomatic process, it lies beneath the skin and fascia, and its pulsations may be readily felt during the administration of an anæsthetic, or under circumstances where the radial pulse is not available; it may be easily compressed against the bone in order to check bleeding from the temporal region of the scalp. When a flap is raised from this part of the head, for trephining, the incision should be shaped like a horseshoe, with its convexity upwards, so that the flap shall contain the superficial temporal artery, which ensures a sufficient supply of blood.

8. The **internal maxillary artery** (figs. 665, 666), the larger terminal branch of the external carotid artery, arises behind the neck of the mandible, and is at first imbedded in the parotid gland; it passes forwards between the ramus of the mandible and the sphenomandibular ligament, and then runs, either upon or beneath the Pterygoideus externus, to the pterygopalatine fossa. It may be divided into mandibular, pterygoid, and pterygopalatine portions.

The *first or mandibular portion* passes horizontally forwards, between the neck of the mandible and the sphenomandibular ligament, where it lies parallel to and a little below the auriculotemporal nerve; it crosses the inferior alveolar nerve, and runs along the lower border of the Pterygoideus externus.

The *second or pterygoid portion* runs obliquely forwards and upwards under cover of the Temporalis, and superficial to the lower head of the Pterygoideus

FIG. 665.—The right internal maxillary artery.

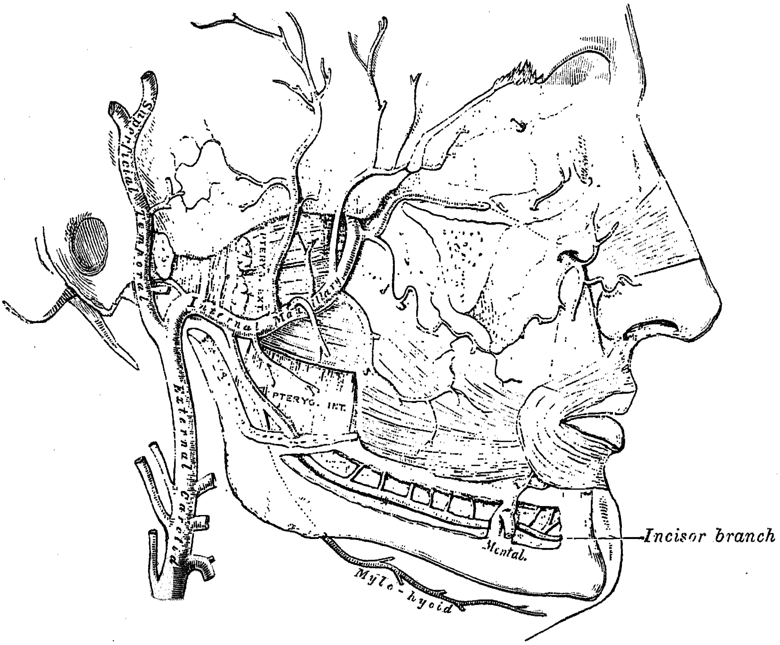
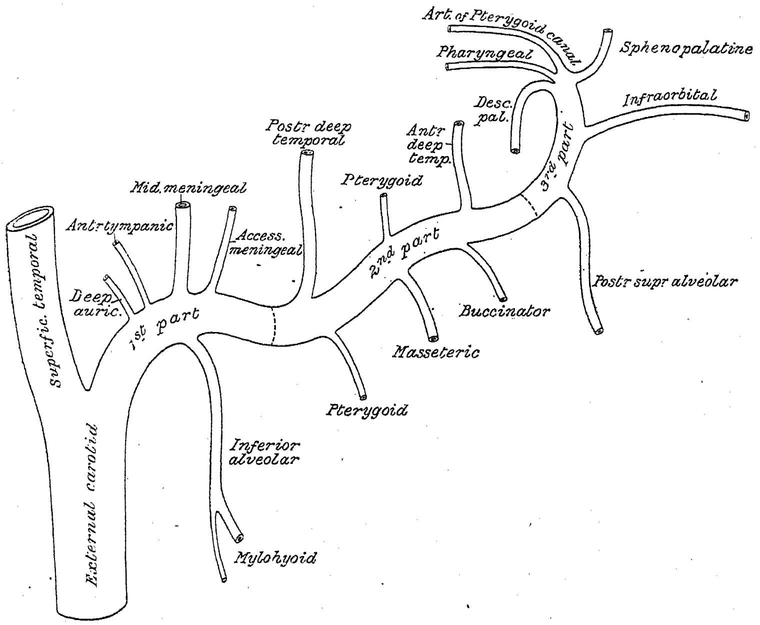


FIG. 666.—A plan of the branches of the internal maxillary artery.



externus; very frequently it lies beneath the latter muscle between it and the branches of the mandibular nerve.

The *third or pterygopalatine portion* passes between the upper and lower heads of the Pterygoideus externus, and through the pterygomaxillary fissure

into the pterygopalatine fossa, where it lies in front of the sphenopalatine ganglion.

The branches of the vessel may be divided into three groups (fig. 666), corresponding with its three portions.

The Branches of the First or Mandibular Portion of the Internal Maxillary Artery (fig. 666)

Deep auricular.	Middle meningeal.
Anterior tympanic.	Accessory meningeal.
Inferior alveolar.	

The **deep auricular artery**, a small branch, often arises in common with the anterior tympanic. It ascends in the substance of the parotid gland, behind the temporomandibular joint, pierces the cartilaginous or bony wall of the external acoustic meatus, and supplies its cuticular lining and the outer surface of the tympanic membrane ; it gives a branch to the mandibular joint.

The **anterior tympanic artery**, a small branch, ascends behind the mandibular joint, and enters the tympanic cavity through the petrotympanic fissure ; it ramifies upon the tympanic membrane, and forms a vascular circle around it with the stylomastoid branch of the posterior auricular artery ; it anastomoses with the artery of the pterygoid canal and with the caroticotympanic branch from the internal carotid artery.

The **middle meningeal artery** is the largest of the meningeal arteries. It ascends between the sphenomandibular ligament and the Pterygoideus externus and between the two roots of the auriculotemporal nerve, and enters the cranial cavity through the foramen spinosum of the sphenoidal bone ; it then runs forwards and lateralwards for a variable distance in a groove on the anterior part of the squama of the temporal bone, and divides into an anterior and a posterior branch. The *anterior branch*, the larger, crosses the great wing of the sphenoidal bone, reaches the groove, or canal, in the sphenoidal angle of the parietal bone, and then divides into branches which spread out between the dura mater and internal surface of the cranium, some passing upwards as far as the vertex, and others backwards to the occipital region. The *posterior branch* curves backwards on the squama of the temporal bone, and, reaching the squamous border of the parietal bone some distance in front of its mastoid angle, divides into branches which supply the posterior part of the dura mater and cranium. The branches of the middle meningeal artery anastomose with the arteries of the opposite side, and with the anterior and posterior meningeal arteries. One branch runs forwards and anastomoses with the recurrent meningeal branch of the lacrimal artery ; an enlargement of this anastomosis explains the occasional origin of the lacrimal artery from the middle meningeal artery.

The middle meningeal artery gives off the following branches within the cranial cavity: 1. Numerous small *ganglionic branches* supply the semilunar ganglion and the roots of the trigeminal nerve. 2. A *superficial petrosal branch* enters the hiatus of the facial canal, gives twigs to the facial nerve and the tympanic cavity, and anastomoses with the stylomastoid branch of the posterior auricular artery. 3. A *superior tympanic artery* runs in the semicanal for the Tensor tympani, and supplies this muscle and the lining membrane of the canal. 4. *Temporal branches* pass through foramina in the great wing of the sphenoid, and anastomose in the temporal fossa with the deep temporal arteries.

Applied Anatomy.—The middle meningeal artery is of considerable surgical importance, as it may be torn in fractures of the temporal region of the skull, or, indeed, by injuries causing separation of the dura mater from the bone without fracture. The injury may be followed by considerable hæmorrhage between the bone and dura mater, which produces symptoms of compression of the brain, and requires trephining for its relief (p. 723). As the compression implicates the motor region of the cortex, paralysis on the opposite side of the body forms the prominent symptom of the lesion. The anterior branch of this artery lies in a groove or a bony canal on the sphenoidal angle of the parietal bone at a point 4 cm. behind the zygomatic process of the frontal bone, and 4·5 cm. above the zygomatic arch. From this point it passes upwards and slightly backwards to the sagittal suture, lying about 1·25 to 2 cm. behind the coronal suture. The posterior branch runs backwards over the squama of the temporal bone. In order to expose the anterior branch of the artery, a point is taken 4 cm. above the zygomatic arch and the same distance behind the zygomatic process of the frontal bone. Here the pin of the trephine is to be applied.

A horseshoe-shaped flap, measuring 8 cm. in length and transversely, and consisting of all the structures of the scalp down to and including the pericranium, is first made, with its base just above the zygomatic arch. This flap is reflected and a 2·5 cm. trephine applied. After the circle of bone has been removed, the blood-clot is exposed, and gently got rid of, and if possible the bleeding point must be found and controlled.

The **accessory meningeal branch** may arise from the internal maxillary artery or from the middle meningeal artery. It enters the cranial cavity through the foramen ovale, and supplies branches to the semilunar ganglion and the dura mater.

The **inferior alveolar artery** (inferior dental artery) descends with the inferior alveolar nerve to the mandibular foramen on the medial surface of the ramus of the mandible. It runs in the mandibular canal, accompanied by the inferior alveolar nerve, and, opposite the first premolar tooth, divides into two branches, incisor and mental. The *incisor* branch is continued forwards below the incisor teeth as far as the middle line, where it anastomoses with the artery of the opposite side; the inferior alveolar artery and its incisor branch give off a few twigs to the mandible, and a series of branches which correspond in number to the roots of the teeth; these enter the minute apertures at the extremities of the roots, and supply the pulp of the teeth. The *mental* branch escapes at the mental foramen, supplies the chin, and anastomoses with the submental and inferior labial arteries. Near its origin the inferior alveolar artery gives off a *lingual* branch which descends with the lingual nerve and supplies the mucous membrane of the mouth. Before the inferior alveolar artery enters the mandibular foramen, it gives off a *mylohyoid* branch which pierces the sphenomandibular ligament, and descends with the mylohyoid nerve in the mylohyoid groove on the ramus of the mandible; it ramifies on the superficial surface of the Mylohyoideus and anastomoses with the submental branch of the external maxillary artery.

The Branches of the Second or Pterygoid Portion of the Internal Maxillary Artery (fig. 666)

Deep temporal. Pterygoid. Masseteric. Buccinator.

The **deep temporal branches,** an anterior and a posterior, ascend between the Temporalis and the pericranium; they supply the muscle, and anastomose with the middle temporal artery; the anterior communicates with the lacrimal artery by means of small branches which perforate the zygomatic bone and great wing of the sphenoidal bone.

The **pterygoid branches,** irregular in their number and origin, supply the Pterygoidei.

The **masseteric artery** is small and passes with the masseteric nerve behind the tendon of the Temporalis, and through the mandibular notch to the deep surface of the Masseter. In the substance of that muscle it anastomoses with the masseteric branches of the external maxillary artery and with branches of the transverse facial artery.

The **buccinator artery** is small and runs obliquely forwards with the buccinator nerve, between the Pterygoideus internus and the insertion of the Temporalis, to the outer surface of the Buccinator, to which it is distributed, anastomosing with branches of the external maxillary and infra-orbital arteries.

The Branches of the Third or Pterygopalatine Portion of the Internal Maxillary Artery (fig. 666)

Posterior superior alveolar.	Pharyngeal.
Infra-orbital.	Artery of the pterygoid canal.
Descending palatine.	Sphenopalatine.

The **posterior superior alveolar artery** (posterior dental artery) is given off from the internal maxillary artery as that vessel enters the pterygopalatine fossa; it frequently arises in conjunction with the infra-orbital artery. Descending upon the infratemporal surface of the maxilla, it divides into branches, some of which supply the molar and premolar teeth and the lining of the maxillary sinus, while others are continued forwards on the alveolar process to supply the gums.

The **infra-orbital artery** often arises in conjunction with the posterior superior alveolar artery. It enters the orbital cavity through the posterior part of the inferior orbital fissure, runs along the infra-orbital groove and canal with the infra-orbital nerve, and emerges with the nerve on the face through the infra-orbital foramen, beneath the infra-orbital head of the Quadratus labii superioris. Whilst in the canal, it gives off (*a*) *orbital* branches which assist in supplying the Rectus inferior and Obliquus inferior and the lacrimal sac, and (*b*) *anterior superior alveolar* branches which descend through the anterior alveolar canals to supply the upper incisor and canine teeth and the mucous membrane of the maxillary sinus. On the face, some branches ascend to the medial angle of the orbit and the lacrimal sac, anastomosing with the angular branch of the external maxillary artery; others run towards the nose, anastomosing with the dorsal nasal branch of the ophthalmic artery; and others descend between the Quadratus labii superioris and the Caninus, and anastomose with the external maxillary, transverse facial, and buccinator arteries.

The remaining branches of the internal maxillary artery arise from that portion of the artery which is contained in the pterygopalatine fossa.

The **descending palatine artery** descends through the pterygopalatine canal with the anterior palatine branch of the sphenopalatine ganglion, and gives off two or three *smaller palatine arteries* which are transmitted through the lesser palatine canals to supply the soft palate and palatine tonsil, and to anastomose with the ascending palatine artery. The continuation of the vessel is named the *greater palatine artery*; it emerges on the oral surface of the palate through the greater palatine foramen, runs forwards in a groove near the alveolar border of the hard palate to the incisive canal; its terminal part passes upwards through this canal, and anastomoses with a branch of the sphenopalatine artery. Branches are distributed to the gums, the palatine glands, and the mucous membrane of the roof of the mouth.

Applied Anatomy.—The position of the descending palatine artery on the hard palate should be borne in mind in performing an operation for the closure of a cleft in the hard palate, as it is in danger of being wounded, and may give rise to formidable hæmorrhage; it has even been found necessary to plug the pterygopalatine canal in order to arrest the bleeding.

The **pharyngeal branch** is very small; it runs backwards through the pharyngeal canal with the pharyngeal nerve, and is distributed to the roof of the nose and pharynx, to the sphenoidal air-sinus, and the auditory tube.

The **artery of the pterygoid canal** (Vidian artery), frequently a branch of the descending palatine artery, passes backwards along the pterygoid canal with the corresponding nerve. It is distributed to the upper part of the pharynx and to the auditory tube, and sends into the tympanic cavity a small branch which anastomoses with the other tympanic arteries.

The pharyngeal branch and the artery of the pterygoid canal lie on the medial and lateral aspects respectively of the sphenopalatine ganglion, while the trunk of the internal maxillary artery is in front of it.

The **sphenopalatine artery** is really the terminal part of the internal maxillary artery; it passes through the sphenopalatine foramen into the cavity of the nose, at the posterior part of the superior meatus. Here it gives off its *posterior lateral nasal* branches which ramify over the conchæ and meatuses, anastomose with the ethmoidal arteries and the nasal branches of the descending palatine artery, and assist in supplying the frontal, maxillary, ethmoidal, and sphenoidal air-sinuses. Crossing the anterior part of the under surface of the sphenoidal bone, the sphenopalatine artery ends on the nasal septum as the *posterior septal* branches, which anastomose with the ethmoidal arteries and the septal branch of the superior labial artery; one branch descends in a groove on the vomer to the incisive canal and anastomoses with the terminal ascending branch of the greater palatine artery.

The Triangles of the Neck (fig. 667)

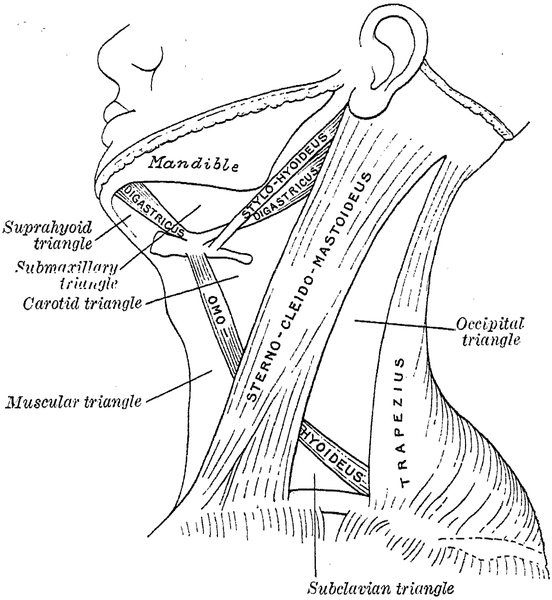
The side of the neck presents a somewhat quadrilateral outline, limited, above, by the lower border of the body of the mandible, and a line drawn

from the angle of the mandible to the mastoid process; below, by the upper border of the clavicle; in front, by the middle line of the neck; behind, by the anterior margin of the Trapezius. This space is subdivided by the Sternocleidomastoideus, which passes obliquely across the neck, from the sternum and clavicle below, to the mastoid process and occipital bone above. The area in front of this muscle is called the *anterior triangle* of the neck; that behind it, the *posterior triangle*.

The Anterior Triangle of the Neck (fig. 667)

The **anterior triangle** of the neck is bounded anteriorly by the middle line of the neck, posteriorly, by the anterior margin of the Sternocleidomastoideus; its base, directed upwards, is formed by the lower border of the body of the mandible, and a line from the angle of the mandible to the mastoid process: its apex is below, at the sternum. This triangle is subdivided into muscular, carotid, submaxillary, and suprahyoid triangles.

Fig. 667.—The triangles of the neck.



The **muscular, or inferior carotid, triangle** is bounded, in front, by the median line of the neck from the hyoid bone to the sternum; behind and below, by the anterior margin of the Sternocleidomastoideus; behind and above, by the superior belly of the Omohyoideus. It is covered by the skin, superficial fascia, Platysma, and deep fascia, ramifying in which are some of the branches of the cutaneous cervical and supraclavicular nerves. Beneath these superficial structures are the Sternohyoideus and Sternothyreoideus, which, together with the anterior margin of the Sternocleidomastoideus, conceal the lower part of the carotid sheath and its contents. In front of the sheath are a few descending filaments from the ansa hypoglossi; behind the sheath are the inferior thyreoid artery, the recurrent nerve, and the sympathetic trunk; and on its medial side, the œsophagus, the trachea, the thyreoid gland, and the lower part of the larynx.

The **carotid triangle** is limited, behind, by the Sternocleidomastoideus; in front and below, by the superior belly of the Omohyoideus; and above, by the Stylohyoideus and the posterior belly of the Digastricus. It is covered by the skin, superficial fascia, Platysma, and deep fascia, ramifying in which are branches of the facial and the cutaneous cervical nerves. Its floor is formed by parts of the Thyreohyoideus, Hyoglossus, and the Constrictores pharyngis medius et inferior. When this space is dissected it is seen to contain the upper part of the common carotid artery, which divides opposite the superior border of the thyreoid cartilage into the external and internal carotid arteries. These vessels are overlapped by the anterior margin of the Sternocleidomastoideus. The external and internal carotid arteries lie side by side, the external being the more anterior. The following branches of the external carotid artery are also met with: the superior thyreoid, running forwards and downwards; the lingual, directly forwards; the external maxillary,

forwards and upwards; the occipital, backwards; and the ascending pharyngeal, directly upwards on the medial side of the internal carotid. The veins met with are: the internal jugular, which lies on the lateral side of the common and internal carotid arteries; and veins corresponding to the above-mentioned branches of the external carotid artery—viz. the superior thyreoid, the lingual, common facial, ascending pharyngeal, and sometimes the occipital—all of which end in the internal jugular vein. The hypoglossal nerve crosses both the internal and external carotid arteries, curving round the origin of the occipital artery; in this position it gives off its descending ramus which runs down in front of the carotid sheath. Within the sheath, between the common carotid artery and the internal jugular vein, and behind both, is the vagus nerve; behind the sheath, the sympathetic trunk. The accessory nerve appears at the lower border of the posterior belly of the Digastricus, and descends for a short distance on the lateral side of the vessels before it pierces the Sternocleidomastoideus. On the medial side of the external carotid artery, below the hyoid bone, is the internal branch of the superior laryngeal nerve; and, still more inferiorly, the external branch of the same nerve. The upper portion of the larynx and lower portion of the pharynx are also found in the anterior part of this triangle.

The **submaxillary, or digastric, triangle** is bounded, above, by the lower border of the body of the mandible, and a line drawn from its angle to the mastoid process; below, by the posterior belly of the Digastricus and the Stylohyoideus; in front, by the anterior belly of the Digastricus. It is covered by the skin, superficial fascia, Platysma, and deep fascia, ramifying in which are branches of the facial and cutaneous cervical nerves. Its floor is formed by the Mylohyoideus, Hyoglossus, and Constrictor pharyngis superior. It is divided into an anterior and a posterior part by the stylomandibular ligament. The anterior part contains the submaxillary gland, superficial to which is the anterior facial vein, while imbedded in a groove on the posterior border of the gland is the external maxillary artery; beneath the gland, on the surface of the Mylohyoideus, are the submental artery and the mylohyoid artery and nerve. The posterior part of this triangle contains the external carotid artery, which ascends deeply in the substance of the parotid gland; in this triangle the external carotid artery is in front of, and superficial to, the internal carotid artery, and is crossed by the facial nerve; it gives off in its course the posterior auricular, superficial temporal, and internal maxillary branches: more deeply placed, and separated from the external carotid artery by the Styloglossus, the Stylopharyngeus, and the glossopharyngeal nerve, are the internal carotid artery, the internal jugular vein, and the vagus nerve.

The **suprahyoid triangle** is limited on either side by the anterior belly of the Digastricus; its apex is at the mandible; its base is formed by the body of the hyoid bone, and its floor by the Mylohyoidei. It contains one or two lymph-glands and some small veins; the latter unite to form the anterior jugular vein.

The Posterior Triangle of the Neck (fig. 667)

The **posterior triangle** of the neck is bounded, in front, by the Sternocleidomastoideus; behind, by the anterior margin of the Trapezius; its base is formed by the middle one-third of the clavicle; its apex is at the occipital bone between the attachments of the Sternocleidomastoideus and the Trapezius. The triangle is crossed, about 2·5 cm. above the clavicle, by the inferior belly of the Omohyoideus, which divides the triangle into an occipital and a subclavian triangle.

The **occipital triangle,** the upper and larger division of the posterior triangle, is bounded in front by the Sternocleidomastoideus; behind, by the Trapezius; below, by the Omohyoideus. Its floor is formed from above downwards by the Splenius capitis, Levator scapulæ, and the Scaleni medius et posterior; sometimes a small part of the Semispinalis capitis is seen at the apex of the triangle. It is covered by the skin, the superficial and deep fasciæ,

and by the Platysma below. The accessory nerve pierces the Sternocleidomastoideus and is directed obliquely across the space to the under surface of the Trapezius; while the cutaneous and muscular branches of the cervical plexus appear at the posterior border of the Sternocleidomastoideus; below, the supraclavicular nerves and the transverse cervical vessels and the upper part of the brachial plexus cross the space. A chain of lymph-glands is also found running along the posterior border of the Sternocleidomastoideus, from the mastoid process to the root of the neck.

The **subclavian triangle,** the lower and smaller division of the posterior triangle, is bounded, above, by the inferior belly of the Omohyoideus; below, by the clavicle; its base is formed by the lower part of the posterior border of the Sternocleidomastoideus. Its floor consists of the first rib and the first digitation of the Serratus anterior. The size of this triangle varies with the extent of attachment of the clavicular portions of the Sternocleidomastoideus and Trapezius, and also with the level at which the inferior belly of the Omohyoideus crosses the neck; this level is lowered when the arm is raised, and raised when the arm is depressed. The triangle is covered by the skin, the superficial and deep fasciæ, and the Platysma, and crossed by the supraclavicular nerves. Just above the level of the clavicle, the third portion of the subclavian artery curves lateralwards and downwards from the lateral margin of the Scalenus anterior, across the first rib, to the axilla. The subclavian vein lies behind the clavicle, and is not usually seen in this space; but in some cases it rises as high as the artery, and has even been seen to accompany that vessel behind the Scalenus anterior. The brachial plexus of nerves lies partly above and partly behind the artery, and in close contact with it. Passing transversely behind the clavicle are the transverse scapular vessels; and running in the same direction, but at a slightly higher level are the transverse cervical artery and vein. The external jugular vein descends behind the posterior border of the Sternocleidomastoideus, to terminate in the subclavian vein; it receives the transverse cervical and transverse scapular veins, which form a plexus in front of the third part of the subclavian artery, and occasionally it is joined by a small vein which crosses the clavicle from the cephalic vein. The small nerve to the Subclavius also crosses this triangle about its middle, and some lymph-glands are contained within the space.

The Internal Carotid Artery

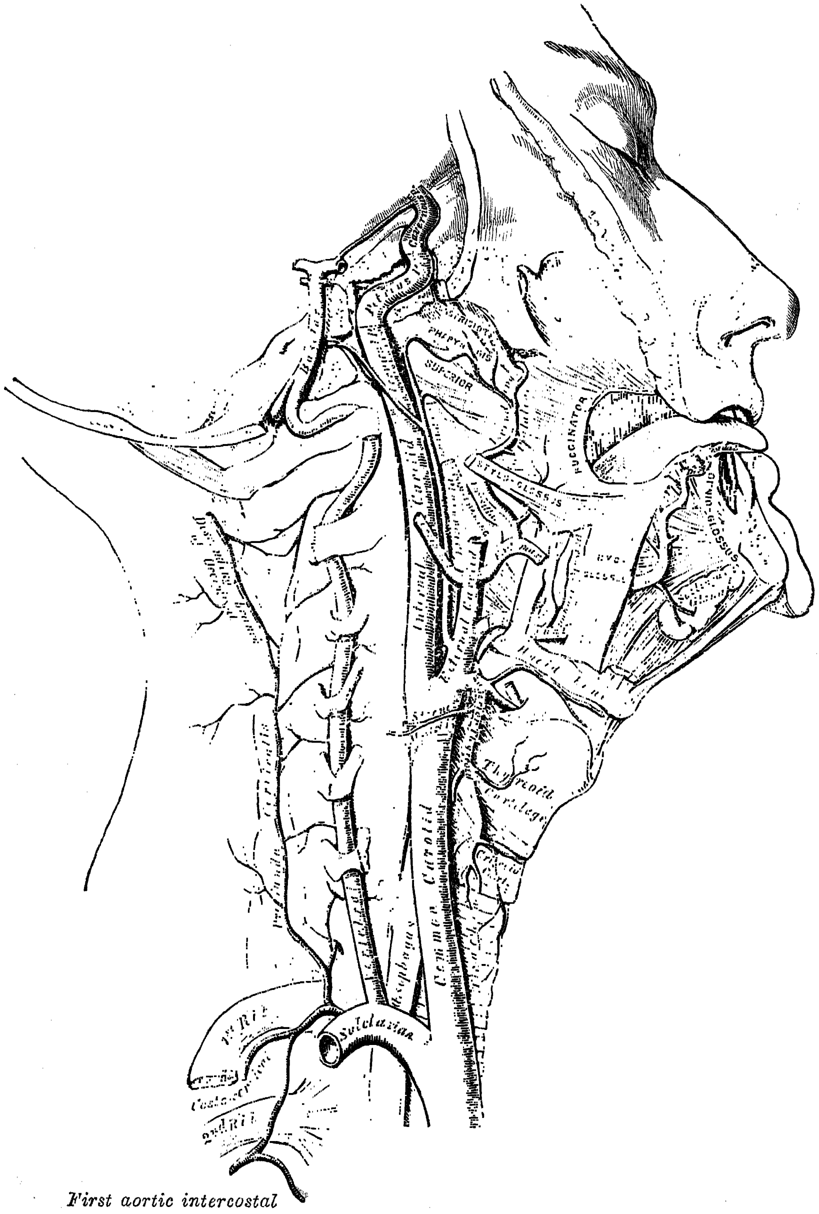
The **internal carotid artery** (fig. 668) supplies the greater part of the cerebral hemisphere, the eye and its appendages, and sends branches to the forehead and nose. It begins at the bifurcation of the common carotid artery, ascends to the base of the skull, and enters the cranial cavity through the carotid canal of the temporal bone. It then runs forward through the cavernous sinus, lying in the carotid sulcus on the side of the body of the sphenoidal bone, and ends below the anterior perforated substance of the brain by dividing into the anterior and the middle cerebral arteries.

The internal carotid artery may be divided into four portions: cervical, petrous, cavernous, and cerebral.

The **cervical portion.**—This portion of the internal carotid artery begins at the bifurcation of the common carotid artery, at the upper border of the thyreoid cartilage, and ascends in front of the transverse processes of the upper three cervical vertebræ to the lower end of the carotid canal in the petrous portion of the temporal bone. It is comparatively superficial at its commencement, where it is contained in the carotid triangle, and lies behind and lateral to the external carotid artery, overlapped by the Sternocleidomastoideus, and covered by the deep fascia, Platysma, and skin; it then passes beneath the parotid gland, being crossed by the hypoglossal nerve, the Digastricus and Stylohyoideus, and the occipital and posterior auricular arteries. Higher up, it is separated from the external carotid artery by the Styloglossus and Stylopharyngeus, the tip of the styloid process and the stylohyoid ligament, the glossopharyngeal nerve and the pharyngeal branch of the vagus. It is in relation, *behind,* with the Longus capitis, the superior cervical ganglion of the sympathetic trunk, and the superior laryngeal nerve; *laterally,*

with the internal jugular vein and vagus nerve, the nerve lying on a plane posterior to the artery; *medially*, with the pharynx, superior laryngeal nerve, and ascending pharyngeal artery. At the base of the skull the glossopharyngeal, vagus, accessory, and hypoglossal nerves lie between the internal carotid artery and the internal jugular vein.

FIG. 668.—The right internal carotid and vertebral arteries.

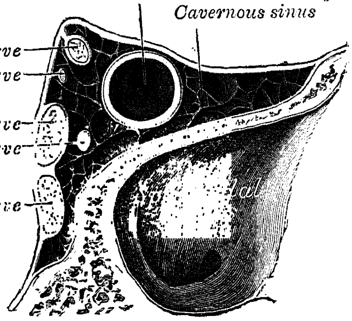


The **petrous portion.**—When the internal carotid artery enters the carotid canal in the petrous portion of the temporal bone, it first ascends, then curves forwards and medialwards, and again ascends as it leaves the canal to enter the cranial cavity between the lingula and petrosal process of the sphenoidal bone. The artery lies at first in front of the cochlea and tympanic cavity; it is separated from

the latter cavity and from the auditory tube by a thin, bony lamella, which is cribriform in the young subject, and often partly absorbed in old age. Farther forwards it is separated from the semilunar ganglion by a thin plate of bone, which forms the floor of the trigeminal impression and the roof of the horizontal portion of the carotid canal. Frequently this bony plate is more or less deficient, and then the ganglion is separated from the artery by fibrous membrane. The artery is surrounded by a number of small veins and by the carotid plexus of nerves which is derived from the ascending branch of the superior cervical ganglion of the sympathetic trunk.

The **cavernous portion** of the internal carotid artery is situated in the cavernous sinus, but is covered by the lining membrane of the sinus. It at first ascends towards the posterior clinoid process, then passes forwards on the side of the body of the sphenoidal bone, and again curves upwards on the medial side of the anterior clinoid process, and perforates the dura mater forming the roof of the sinus; occasionally the anterior and middle clinoid processes form a bony ring round the artery. The cavernous portion of the artery is surrounded by the cavernous plexus of the sympathetic, and lateral to it are the oculomotor, trochlear, ophthalmic and abducent nerves (fig. 669).

Fig. 669.—An oblique section through the left cavernous sinus.



The **cerebral portion.**—After perforating the dura mater on the medial side of the anterior clinoid process, the internal carotid artery passes between the optic and oculomotor nerves to the anterior perforated substance at the medial end of the lateral cerebral fissure, where it divides into the anterior and middle cerebral arteries.

Peculiarities.—The length of the internal carotid artery varies with the length of the neck, and with the point of bifurcation of the common carotid. It arises occasionally from the arch of the aorta, and then has been found on the medial side of the external carotid, as far as the larynx, where it crossed behind the latter vessel to reach its usual position. The course of the artery, instead of being straight, may be very tortuous. A few instances are recorded in which it was absent; in one of these the common carotid artery passed up the neck, and gave off the branches normally arising from the external carotid; the cranial portion of the internal carotid artery was replaced by two branches of the internal maxillary artery, which entered the skull through the foramen rotundum and foramen ovale, and joined to form a single vessel.

Applied Anatomy.—The cervical part of the internal carotid artery is very rarely wounded. Although the internal carotid lies about 2 cm. behind and lateral to the tonsil, instances have occurred in which the artery has been wounded during the operation of excision of the tonsil, and fatal hæmorrhage has supervened. The incision for ligature of the cervical portion of the internal carotid should be made along the anterior border of the Sternocleidomastoideus, from the angle of the mandible to the upper border of the thyreoid cartilage. The superficial structures being divided, and the Sternocleidomastoideus defined and drawn backwards, the areolar tissue must be carefully separated, and the posterior belly of the Digastricus and the hypoglossal nerve sought as guides to the vessel. The external carotid should be drawn medialwards and the Digastricus upwards, and the aneurysm needle passed from the lateral to the medial side of the vessel.

Obstruction of the internal carotid by embolism or thrombosis may give rise to symptoms of cerebral anæmia and softening if the collateral circulation is ill-developed. The patient suffers from giddiness, with failure of the mental powers; and convulsions, coma, or hemiplegia on the opposite side of the body, may be observed.

Ligature of the internal carotid artery is not so effective as ligature of the common carotid artery in diminishing the blood supply to the brain, because blood is conveyed to the brain through the anastomoses of the branches of the external carotid artery with the branches of the petrous and cavernous parts of the internal carotid artery—especially with the ophthalmic artery.

Branches.—No branches arise from the cervical portion of the internal carotid artery. Those from the other portions are :

From the petrous portion	1. Caroticotympanic. 2. Pterygoid.
From the cavernous portion	3. Cavernous. 4. Hypophysial. 5. Semilunar. 6. Anterior meningeal. 7. Ophthalmic.
From the cerebral portion	8. Anterior cerebral. 9. Middle cerebral. 10. Posterior communicating. 11. Anterior chorioidal.

1. The **caroticotympanic branch** is small ; it enters the tympanic cavity through a foramen in the wall of the carotid canal, and anastomoses with the anterior tympanic branch of the internal maxillary artery, and with the stylomastoid artery.

2. A small, inconstant **pterygoid branch** passes into the pterygoid canal with the nerve of that canal, and anastomoses with a branch of the descending palatine artery.

3. The **cavernous branches** are numerous small vessels which supply the semilunar ganglion, and the walls of the cavernous and inferior petrosal sinuses. Some of them anastomose with branches of the middle meningeal artery.

4. The **hypophysial branches** are one or two minute vessels which supply the hypophysis.

5. The **semilunar branches** are small vessels supplying the semilunar ganglion.

6. The **anterior meningeal branch** is a minute branch which passes over the small wing of the sphenoid to supply the dura mater of the anterior cranial fossa ; it anastomoses with the meningeal branch from the posterior ethmoidal artery.

7. The **ophthalmic artery** (fig. 670) arises from the internal carotid artery, as that vessel emerges from the cavernous sinus, on the medial side of the anterior clinoid process ; it enters the orbital cavity through the optic foramen, below and lateral to the optic nerve. In the orbital cavity it runs for a short distance lateral to the optic nerve and medial to the oculomotor, trochlear and abducent nerves, the ciliary ganglion, and the Rectus lateralis. It next crosses obliquely above the optic nerve and beneath the Rectus superior to reach the medial wall of the orbit. It then runs forwards between the Obliquus superior and the Rectus medialis, and, at the medial end of the upper eyelid, divides into two branches, named *frontal* and *dorsal nasal*. As the artery crosses the optic nerve it is accompanied by the nasociliary nerve, and is separated from the frontal nerve by the Rectus superior and Levator palpebræ superioris ; the terminal part of the artery is accompanied by the infratrochlear nerve. In about 15 per cent. of subjects the ophthalmic artery crosses below the optic nerve.

The branches of the ophthalmic artery are :—

Central artery of the retina.	Long posterior ciliary.	Anterior meningeal.
Lacrimal.	Anterior ciliary.	Medial palpebral.
Muscular.	Supra-orbital.	Frontal.
Short posterior ciliary.	Posterior ethmoidal.	Dorsal nasal.
	Anterior ethmoidal.	

The **central artery of the retina**, the first and one of the smallest branches of the ophthalmic artery, arises from that vessel whilst it lies beneath the optic nerve. It runs for a short distance within the dural sheath of the optic nerve, and about 1·25 cm. behind the eyeball it pierces the inferomedial surface of the nerve, and runs forward in the centre of the nerve to the retina. Its mode of distribution is described with the anatomy of the eye.

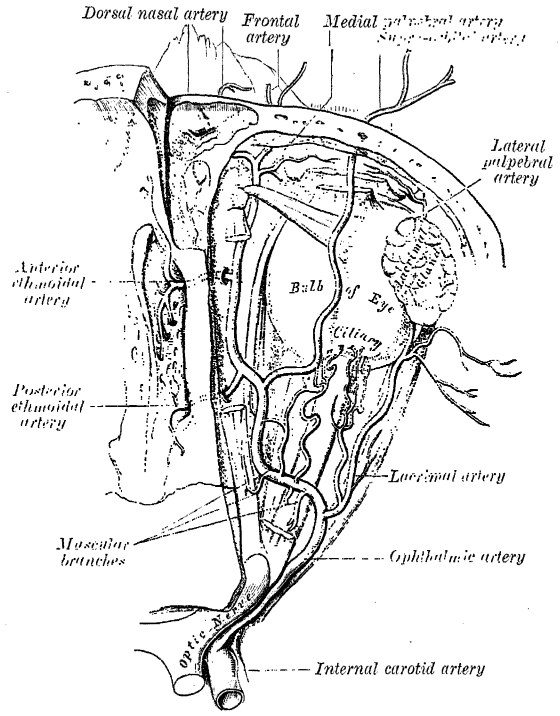
The **lacrimal artery** arises from the ophthalmic artery close to the optic foramen, and is one of its largest branches ; sometimes it is given off before the ophthalmic artery enters the orbit ; occasionally its place is taken by a branch of the middle meningeal artery (p. 618). It accompanies the lacrimal nerve along the upper border of the Rectus lateralis, and supplies the lacrimal gland. Its terminal branches, escaping from the gland, are distributed to the eyelids and conjunctiva : of those supplying the eyelids, two are of considerable size and are named the **lateral palpebral arteries** ; they run medialwards in the upper and lower lids respectively and anastomose with the medial palpebral arteries. The lacrimal artery gives off one or two **zygomatic branches**, one of which passes through

the zygomaticotemporal foramen to the temporal fossa, and anastomoses with the deep temporal arteries; another appears on the cheek through the zygomaticofacial foramen and anastomoses with the transverse facial artery. A **recurrent meningeal branch** passes backwards through the lateral part of the superior orbital fissure, and anastomoses with a branch of the middle meningeal artery.

The **muscular branches** frequently spring from a common trunk. They consist of a superior and an inferior group, and most of them accompany the branches of the oculomotor nerve. The superior group supplies the Levator palpebræ superioris, Recti superior et lateralis, and Obliquus superior. The inferior group, more constantly present, is distributed to the Recti medialis et inferior, and the Obliquus inferior. This group gives off most of the anterior ciliary arteries. Additional muscular branches are derived from the lacrimal and supra-orbital arteries, or from the trunk of the ophthalmic artery.

The **ciliary arteries** are divisible into three groups, long and short posterior, and anterior. The **long posterior ciliary arteries,** two in number, pierce the posterior part of the sclera a short distance from the entrance of the optic nerve, and run forwards, along either side of the eyeball, between the sclera and chorioid, to the ciliary muscle, where each divides into a superior and an inferior branch; these form, together with the anterior ciliary arteries, an arterial circle, the **circulus arteriosus major,** around the circumference of the iris; from the circulus arteriosus major numerous converging branches run in the substance of the iris to its pupillary margin, where they form a second arterial circle, the **circulus arteriosus minor.** The **short posterior ciliary arteries,** about seven in number, pass forwards around the optic nerve to the posterior part of the eyeball, and, after dividing into from fifteen to twenty branches, pierce the sclera around the entrance of the nerve, and supply the chorioid coat and the ciliary processes. The **anterior ciliary arteries** are derived from the muscular branches of the ophthalmic artery; they run to the front of the eyeball in company with the tendons of the Recti, form a vascular zone beneath the conjunctiva, and then pierce the sclera a short distance from the sclerocorneal junction and end in the circulus arteriosus major.

FIG. 670.—The ophthalmic artery and its branches.



The **supra-orbital artery** leaves the ophthalmic artery as that vessel crosses the optic nerve. It ascends on the medial borders of the Rectus superior and Levator palpebræ superioris, and meeting the supra-orbital nerve accompanies it between the periosteum and Levator palpebræ superioris to the supra-orbital foramen; passing through this foramen it divides into a superficial and a deep branch, which supply the skin, muscles, and pericranium of the forehead, anastomosing with the frontal artery, the frontal branch of the superficial temporal artery, and the artery of the opposite side. In the orbit it supplies twigs to the Rectus superior and the Levator palpebræ, and sends a branch across the pulley of the Obliquus superior, to the parts at the medial palpebral commissure. At the supra-orbital foramen it frequently sends a branch to the diploë.

The **posterior ethmoidal artery** runs through the posterior ethmoidal canal, supplies the posterior ethmoidal air-sinuses, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches which descend into the nasal cavity through the lamina cribrosa of the ethmoidal bone, to anastomose with branches of the sphenopalatine artery.

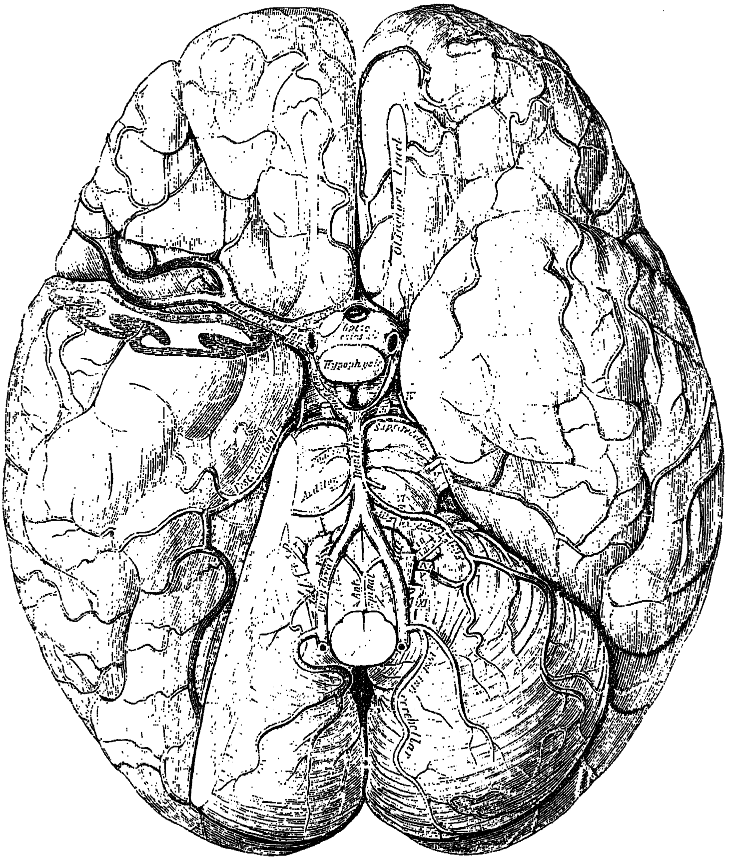
The **anterior ethmoidal artery** accompanies the anterior ethmoidal nerve through the anterior ethmoidal canal, supplies the anterior and middle ethmoidal and frontal air-sinuses, and, entering the cranium, gives off a meningeal branch to the dura mater, and nasal branches; the latter descend into the nasal cavity with the anterior ethmoidal nerve and, running along the groove on the inner surface of the nasal bone, supply twigs to the

lateral wall and septum of the nose, and a terminal branch which appears on the dorsum of the nose between the nasal bone and the lateral nasal cartilage.

The **anterior meningeal artery** is a small branch which passes to the middle cranial fossa through the superior orbital fissure and anastomoses with the middle and accessory meningeal arteries.

The **medial palpebral arteries**, two in number, superior and inferior, arise from the ophthalmic artery below the pulley of the Obliquus superior. They descend behind the lacrimal sac, and enter the eyelids where each divides into two branches which course lateralwards along the edges of the tarsal plates, thus forming two arches (a superior and an inferior) in each eyelid. The superior palpebral artery anastomoses with the supra-orbital artery, and, at the lateral part of the eyelid, with the zygomatico-orbital branch

Fig. 671.—The arteries at the base of the brain.



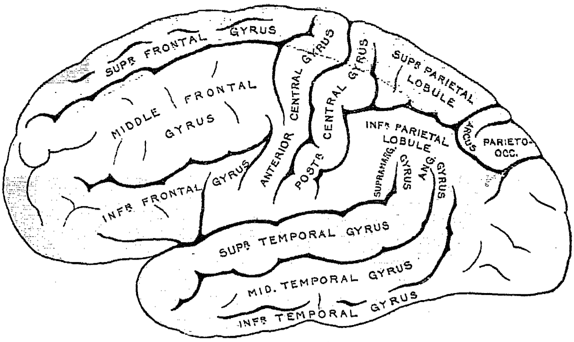
of the temporal artery, and with the upper of the two lateral palpebral branches of the lacrimal artery. The inferior palpebral artery anastomoses at the lateral part of the eyelid with the lower of the two lateral palpebral branches of the lacrimal artery and with the transverse facial artery, and at the medial part of the eyelid with a twig from the angular artery; from this last anastomosis a branch passes to the nasolacrimal duct, ramifying in its mucous membrane, as far as the inferior meatus of the nasal cavity.

The **frontal artery**, one of the terminal branches of the ophthalmic artery, leaves the orbit at its medial angle, with the supratrochlear nerve, and, ascending on the forehead, supplies the skin, muscles, and pericranium, anastomosing with the supra-orbital artery, and with the artery of the opposite side.

The **dorsal nasal artery**, the other terminal branch of the ophthalmic artery, emerges from the orbit between the trochlea of the Obliquus superior and the medial palpebral ligament, and, after giving a twig to the upper part of the lacrimal sac, divides into two branches, one of which crosses the root of the nose, and anastomoses with the angular artery; the other runs along the dorsum of the nose, supplies its outer surface, and anastomoses with the artery of the opposite side, and with the lateral nasal branch of the external maxillary artery.

8. The **anterior cerebral artery** (figs. 671, 672, 673) arises from the internal carotid artery, at the medial end of the lateral cerebral fissure. It passes forwards and medialwards across the anterior perforated substance, above the optic nerve, to the commencement of the longitudinal fissure. Here it comes into close relationship with the opposite artery and is joined to it by a short transverse trunk (sometimes duplicated) named the anterior communicating artery. From this point, the two anterior cerebral arteries run side by side in the longitudinal cerebral fissure, curving round the genu of the corpus callosum, and running backwards along the upper surface of this structure to its posterior extremity, where they end by anastomosing with the posterior cerebral arteries.

FIG. 672.—The lateral surface of the cerebral hemisphere, showing the areas supplied by the cerebral arteries. In this and the next figure the areas supplied by the anterior cerebral artery are coloured *blue*; those by the middle cerebral artery, *pink*; and those by the posterior cerebral artery, *yellow*.



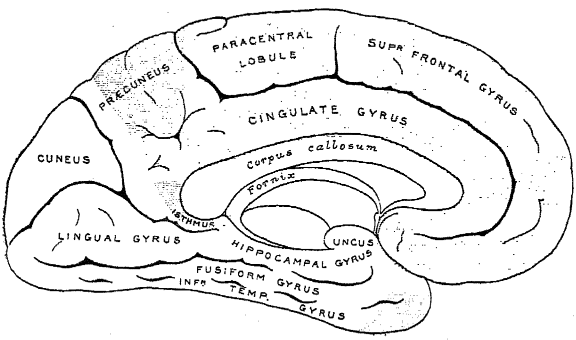
The *anterior communicating artery* has an average length of about 4 mm. and connects the two anterior cerebral arteries across the commencement of the longitudinal fissure; in about 7 per cent. of subjects it is double. It gives off a few anteromedial ganglionic branches.

In its course the anterior cerebral artery gives off the following branches :

Anteromedial ganglionic.	Anterior.	Posterior.
Inferior.	Middle.	

The *anteromedial ganglionic branches* are a group of small arteries which arise from the commencement of the anterior cerebral artery; they pierce the anterior perforated substance and lamina terminalis, and supply the rostrum of the corpus callosum, the septum pellucidum, and the head of the caudate nucleus. The *inferior branches*, two or three in number, are distributed to the orbital surface of the frontal lobe, where they supply the olfactory lobe, gyrus rectus, and medial orbital gyrus. The *anterior branches* supply a part of the superior frontal gyrus, and send twigs over the superomedial border of the cerebral hemisphere to the superior and middle frontal gyri and upper part of the anterior central gyrus. The *middle branches* supply the corpus callosum, the cingulate gyrus, the medial surface of the superior frontal gyrus, and the upper part of the anterior central gyrus. The *posterior branches* supply the præcuneus and adjacent lateral surface of the hemisphere.

FIG. 673.—The medial surface of the cerebral hemisphere, showing the areas supplied by the cerebral arteries (see description of fig. 672).



9. The **middle cerebral artery** (figs. 671, 672), the largest branch of the internal carotid artery, runs at first lateralwards in the lateral cerebral fissure and then backwards and upwards on the surface of the insula, where it divides into branches

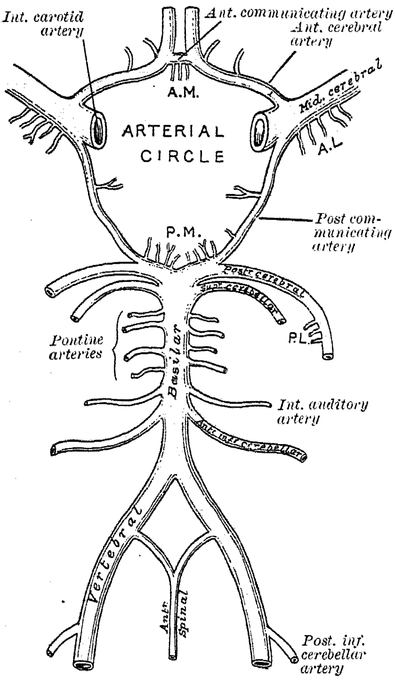
which are distributed to the insula and to the lateral surface of the cerebral hemisphere.

The branches of this vessel are the

Anterolateral ganglionic.	Ascending parietal.
Inferior lateral frontal.	Parietotemporal.
Ascending frontal.	Temporal.

The *anterolateral ganglionic branches* comprise a group of small arteries which arise from the commencement of the middle cerebral artery and enter the substance of the brain through the anterior perforated substance.* They are arranged in two sets: one, the *medial striate*, ascends through the inner segments of the lentiform nucleus, and supplies it, the caudate nucleus, and the internal capsule; the other, the *lateral striate*, ascends through the outer segment of the lentiform nucleus, and supplies the caudate nucleus. One artery of this group is larger than the rest, and of special importance, as being the artery in the brain most frequently ruptured; it has been termed by Charcot the '*artery of cerebral hæmorrhage*.' It ascends between the lentiform nucleus and the external capsule, and ends in the caudate nucleus. The *inferior lateral frontal* supplies the inferior frontal gyrus and the lateral part of the orbital surface of the frontal lobe. The *ascending frontal* supplies the anterior central gyrus. The *ascending parietal* is distributed to the posterior central gyrus and the lower part of the superior parietal lobule. The *parietotemporal* supplies the supramarginal and angular gyri, and the posterior parts of the superior and middle temporal gyri. The *temporal branches*, two or three in number, are distributed to the lateral surface of the temporal lobe.

Fig. 674.—A diagram of the arteries at the base of the brain.



A.L. Anterolateral; A.M. Anteromedial; P.L. Posterolateral; P.M. Posteromedial ganglionic branches.

10. The **posterior communicating artery** (figs. 671, 674) runs backwards from the internal carotid above the oculomotor nerve, and anastomoses with the posterior cerebral, a branch of the basilar artery. It is usually a small vessel, but is occasionally so large that the posterior cerebral may be considered as arising from the internal carotid rather than from the basilar. It is frequently larger on one side than on the other. From its posterior half are given off several small *posteromedial ganglionic branches*, which, with similar vessels from the posterior cerebral artery, pierce the posterior perforated substance and supply the medial surfaces of the thalami and the walls of the third ventricle.

11. The **anterior chorioidal artery**, a small but constant branch, arises from the internal carotid, near the posterior communicating artery. Passing backwards and lateralwards between the uncus and the cerebral peduncle, it enters the inferior horn of the lateral ventricle through the chorioidal fissure and ends in the chorioid plexus. It is distributed to the hippocampus, fimbria, tela chorioidea of the third ventricle, and chorioid plexus.

The arterial circle of Willis.—A considerable part of the brain is supplied by the two vertebral arteries (p. 636), and a remarkable anastomosis, named the *arterial circle of Willis*, exists between these vessels and the two internal carotid arteries. This circle is situated in the cisterna interpeduncularis at the base of the brain, and encloses the optic chiasma and the structures in the interpeduncular fossa (p. 842). It is formed as follows: in front, the two

* Consult an article on 'The basal arteries of the forebrain' by Joseph L. Shellshear, *Journal of Anatomy*, vol. lv. 1920.

anterior cerebral arteries are joined to one another by the anterior communicating artery; behind, the basilar artery (formed by the union of the vertebral arteries) divides into the two posterior cerebral arteries, each of which is joined to the internal carotid artery of the same side by the posterior communicating artery (fig. 674).

THE ARTERIES OF THE BRAIN

The mode of distribution of the vessels of the brain has an important bearing upon a considerable number of the pathological lesions which may occur in this part of the nervous system.

The arteries which supply the brain give origin to two systems of vessels. One of these is named the **ganglionic system,** and its vessels supply the thalami and corpora striata; the other is the **cortical system,** and its vessels ramify in the pia mater and supply the cortex and subjacent brain-substance. These two systems are independent of one another and do not communicate at any point of their peripheral distribution, and there is between the parts supplied by them a borderland of diminished nutritive activity where, it is said, softening of the brain is especially liable to occur.

The **ganglionic system.**—All the vessels of this system are given off from the circle of Willis (p. 630), or from the vessels close to it. They form six principal groups: (I) an **anteromedial group,** derived from the anterior cerebral and anterior communicating arteries; (II) a **posteromedial group,** from the posterior cerebral and posterior communicating arteries; (III and IV) right and left **anterolateral groups,** from the middle cerebral arteries; and (V and VI) right and left **posterolateral groups,** from the posterior cerebral arteries after they have wound round the cerebral peduncles. The vessels of the ganglionic system are larger than those of the cortical system, and are known as end arteries or terminal arteries—that is to say, vessels which from their origin to their termination neither supply nor receive any anastomotic branch, so that, through any one vessel only a limited area of the thalamus or corpus striatum can be injected.

The **cortical system.**—The vessels of this system are the terminal branches of the anterior, middle, and posterior cerebral arteries. They divide in the substance of the pia mater, give off branches which penetrate the brain-cortex perpendicularly, and are divisible into two classes, long and short. The **long or medullary arteries** pass through the grey substance and penetrate the subjacent white substance to the depth of 3 or 4 cm., without intercommunicating otherwise than by very fine capillaries, and thus constitute so many independent small systems. The **short vessels** are confined to the cortex, where they form with the long vessels a compact network in the middle zone of the grey substance, the outer and inner zones being sparingly supplied with blood. The vessels of the cortical system are not so strictly 'terminal' as those of the ganglionic system, but they approach this type very closely, so that injection of one area from the vessel of another area, though possible, is difficult, and only effected through vessels of small calibre; obstruction of one of these vessels may therefore produce softening in a limited area of the brain cortex.

THE ARTERIES OF THE UPPER EXTREMITY

The artery which supplies the upper extremity runs as a single trunk as far as the elbow; but is differently named, according to the regions it traverses. From its origin to the outer border of the first rib it is termed *subclavian*; from the outer border of the first rib to the lower border of the tendon of the Teres major, it is named *axillary*; and from the lower border of the Teres major to a point opposite the neck of the radius it is termed *brachial.*

The Subclavian Arteries (fig. 675)

The right **subclavian artery** arises from the innominate artery, the left from the arch of the aorta. The vessels, therefore, in the first parts of their courses, differ in length, direction, and relation with neighbouring structures.

To facilitate description, each subclavian artery is divided into three parts; the first extends from the origin of the vessel to the medial border of the Scalenus anterior, the second lies behind this muscle, and the third runs from the lateral margin of the muscle to the outer border of the first rib, where it

becomes the axillary artery. The first portions of the two vessels differ from one another in their origin, course and relations, and therefore require separate descriptions. The relations of the second and third parts are almost alike on the two sides of the neck.

The First Part of the Right Subclavian Artery (figs. 668, 675)

The **first part** of the **right subclavian artery** arises from the innominate artery, behind the upper part of the right sternoclavicular articulation, and passes upwards and lateralwards to the medial margin of the Scalenus anterior. It ascends, on an average, about 2 cm. above the clavicle, but the height it reaches varies considerably in different cases.

Relations.—*In front* of the artery are the skin, superficial fascia, Platysma, anterior supraclavicular nerves, deep fascia, the clavicular origin of the Sternocleidomastoideus, the Sternohyoideus, and Sternothyreoideus. It is crossed by the internal jugular and vertebral veins, by the vagus nerve and the cardiac branches of the vagus and sympathetic; the subclavian loop of the sympathetic trunk encircles the vessel. The anterior jugular vein is directed lateralwards in front of the artery, but is separated from it by the Sternohyoideus and Sternothyreoideus. *Below and behind* the artery are the pleura and the apex of the lung; *behind* the artery are the sympathetic trunk, the Longus colli and the first thoracic vertebra. The right recurrent nerve winds round the lower and posterior part of the vessel.

The First Part of the Left Subclavian Artery (figs. 655, 658, 659)

The **first part** of the **left subclavian artery** arises from the arch of the aorta, behind the left common carotid, and at the level of the upper border of the fourth thoracic vertebra; it ascends to the root of the neck and then arches lateralwards to the medial border of the Scalenus anterior.

Relations.—It is in relation, *in front*, with the left vagus, cardiac, and phrenic nerves, the left common carotid artery, the left internal jugular and vertebral veins and the beginning of the left innominate vein, and is covered by the Sternothyreoideus, Sternohyoideus, and Sternocleidomastoideus; *behind*, it is in relation with the œsophagus, thoracic duct, left recurrent nerve, inferior cervical ganglion of the sympathetic trunk, and Longus colli; higher up, however, the œsophagus and thoracic duct lie to its right side, the latter ultimately arching over the vessel to join the angle of union between the subclavian and internal jugular veins. *Medial* to it are the œsophagus, trachea, thoracic duct, and left recurrent nerve; *lateral* to it, the left pleura and lung.

The Second and Third Parts of the Subclavian Artery (fig. 675)

The **second portion** of the subclavian artery lies behind the Scalenus anterior; it is very short, and forms the highest part of the arch described by the vessel.

Relations.—*In front* of it are the skin, superficial fascia, Platysma, deep cervical fascia, Sternocleidomastoideus, and Scalenus anterior. On the right side of the neck the phrenic nerve is separated from the second part of the artery by the Scalenus anterior, while on the left side it crosses the first part of the artery close to the medial edge of the muscle. *Behind* and *below* the vessel are the pleura and lung; *above*, the brachial plexus of nerves. The subclavian vein lies below and in front of the artery, separated from it by the Scalenus anterior.

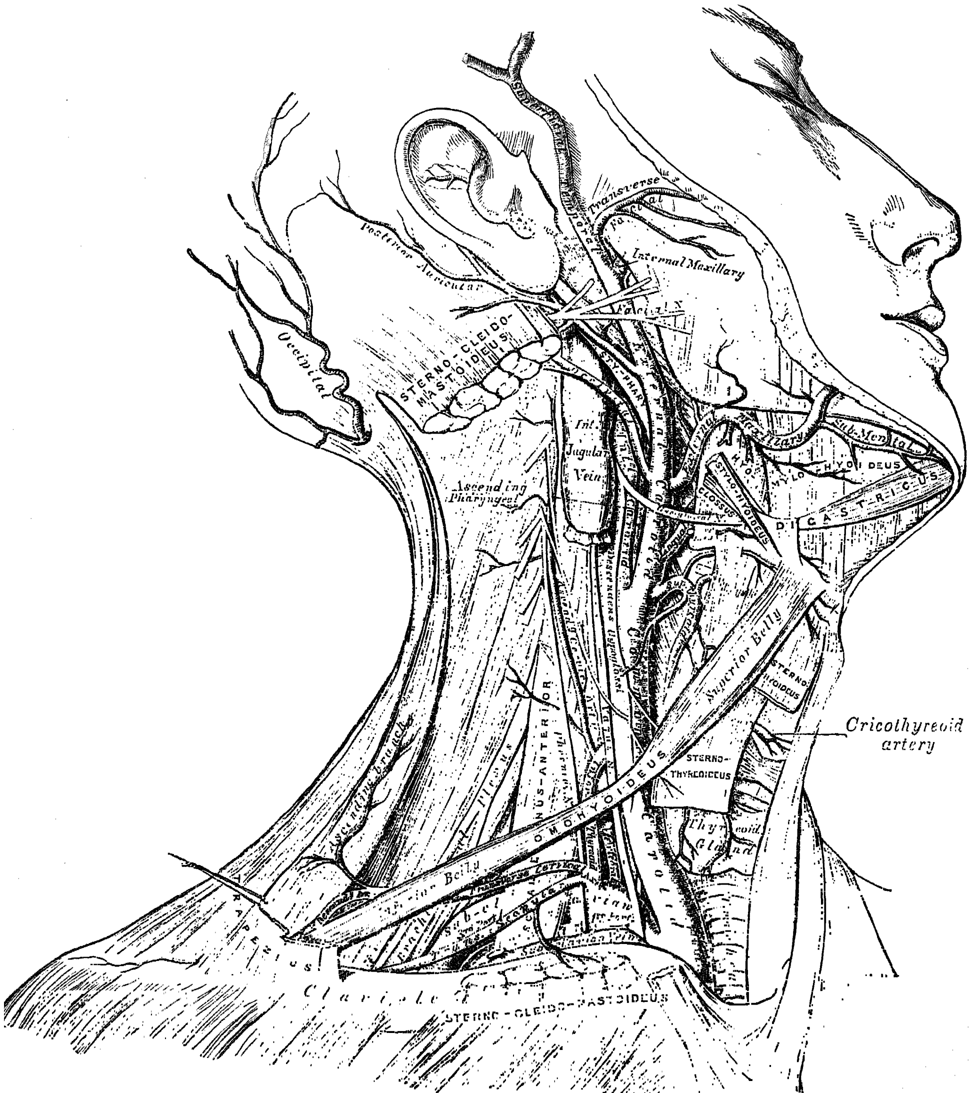
The **third portion** of the subclavian artery runs downwards and lateralwards from the lateral margin of the Scalenus anterior to the outer border of the first rib, where it becomes the axillary artery. This is the most superficial portion of the vessel, and is contained in the subclavian triangle (p. 623).

Relations.—*In front* of it are the skin, the superficial fascia, the Platysma, the supraclavicular nerves, and the deep cervical fascia. The external jugular vein crosses its medial part and receives the transverse scapular, transverse cervical, and anterior jugular veins, which frequently form a plexus in front of the artery.

interposed; higher up, the larynx and pharynx. *Lateral* to the artery are the internal jugular vein and vagus nerve.

At the lower part of the neck, the right recurrent nerve crosses obliquely behind the artery; the right internal jugular vein diverges from the artery, but the left approaches and often overlaps the lower part of the artery. Below the level of

Fig. 660.—A superficial dissection of the right side of the neck, showing the carotid and subclavian arteries.



the sixth cervical vertebra the left common carotid artery is in relation posteriorly with the vertebral artery, the cervical part of the thoracic duct crossing between the two vessels.

Peculiarities.—In about 12 per cent. of subjects the *right* common carotid artery arises above the level of the upper border of the sternoclavicular articulation. It may arise as a separate branch from the arch of the aorta, or in conjunction with the left carotid. The *left* common carotid artery varies in its origin more frequently than the right. In the majority of abnormal cases it arises with the innominate artery; if that artery be absent, the two carotids arise usually by a single trunk. It is rarely joined with the left subclavian, except in cases of transposition of the aortic arch.

the right side, usually behind the trachea, œsophagus, and right carotid, sometimes between the œsophagus and trachea, to the upper border of the first rib, whence it follows its ordinary course.

Occasionally the subclavian artery perforates the Scalenus anterior; very rarely it passes in front of that muscle. Sometimes the subclavian vein passes with the artery behind the Scalenus anterior. The artery may ascend as high as 4 cm. above the clavicle or may only reach the level of the upper border of the bone.

The left subclavian is occasionally joined at its origin with the left carotid. It is more deeply placed than the right subclavian in the first part of its course, and, as a rule, does not reach quite as high a level in the neck.

The posterior border of the Sternocleidomastoideus corresponds closely to the lateral border of the Scalenus anterior, so that the third portion of the artery, the part most accessible for operation, lies immediately lateral to the posterior border of the Sternocleidomastoideus.

Applied Anatomy.—An aneurysm may form on any part of the subclavian artery, except the intrathoracic portion of the left vessel, which is said never to be the seat of aneurysm. The most common site is the third portion (especially on the right side). In this situation it may cause pressure on the brachial plexus, producing pain and numbness in the arm and fingers, with loss of power or paralysis of the muscles of these parts. Œdema of the arm may result from pressure on the subclavian vein. The external jugular vein may become distended and varicose. The treatment is unsatisfactory, since proximal ligature cannot be undertaken with much chance of success; the best treatment is excision of the sac. In aneurysm of the first portion of this artery there is œdema of the head and face, with lividity, congestion of the brain, and semiconsciousness from pressure on the innominate veins as they enter the chest; and spasmodic action of the Diaphragm from pressure on the phrenic nerve. The collateral circulation is so good that blocking of the subclavian artery by embolism or thrombosis often fails to give rise to any striking signs or symptoms, beyond occasional pains in the neck and shoulder and some degree of weakness and wasting in the muscles of the arm.

Compression of the subclavian artery may be required to control hæmorrhage, and can be effectually applied in one situation only, viz. where the artery passes across the upper surface of the first rib. In order to compress the vessel in this situation, the shoulder should be depressed, and the surgeon grasping the side of the neck should press with his thumb in the angle formed by the posterior border of the Sternocleidomastoideus with the upper border of the clavicle, downwards, backwards, and medialwards against the rib; if from any cause the shoulder cannot be sufficiently depressed, pressure may be made from before backwards, so as to compress the artery against the Scalenus medius and transverse process of the seventh cervical vertebra. In appropriate cases, a preliminary incision may be made through the cervical fascia, and the finger may be pressed down directly upon the artery.

In cases of through-and-through gunshot wounds about the clavicle the formation of an arteriovenous aneurysm, or direct communication between the subclavian artery and some neighbouring vein, is not rare. This enables arterial blood at high pressure to escape into the vein; the vein is distended thereby, with the production of a pulsatile swelling that can be felt above or below the clavicle. In addition, a thrill can be felt and a loud rushing murmur can be heard in the neighbourhood of the swelling; both thrill and murmur are continuous, but more forcible during cardiac systole. Not infrequently these arteriovenous aneurysms call for relief by operation.

Ligature of the subclavian artery may be required in cases of wounds, or of aneurysm in the axilla, or in cases of aneurysm on the cardiac side of the point of ligature. The vessel is also ligatured as a preliminary measure to the complete interscapulothoracic amputation of the upper extremity, in which case the transverse scapular and transverse cervical arteries may, if found, be ligatured at the same time, making the 'fore-quarter' amputation an almost bloodless procedure.

The third part of the artery is that which is most favourable for an operation, on account of its being comparatively superficial and most remote from the origin of the large branches. In those cases where the clavicle is not displaced, this operation may be performed with comparative facility; but where the clavicle is pushed up by a large aneurysmal tumour in the axilla, the artery lies at a great depth from the surface, and this materially increases the difficulty. Under these circumstances, it becomes a matter of importance to consider the height to which this vessel reaches above the bone. In ordinary cases, its arch is about 1·25 cm. above the clavicle, occasionally as high as 4 cm., and sometimes so low as to be on a level with its upper border. If the clavicle be displaced, these variations will necessarily make the operation more or less difficult, according as the vessel is less or more accessible.

The procedure in the operation of tying the third portion of the subclavian artery (fig. 662, D) is as follows: The patient being placed on a table in the supine position, with the head drawn over to the opposite side, and the shoulder depressed as much as possible, the skin should be pulled downwards over the clavicle, and an incision made through it, upon that bone, from the anterior border of the Trapezius to the posterior border of the Sternocleidomastoideus. The object in drawing the skin downwards is to avoid any risk

of wounding the external jugular vein, which perforates the deep fascia above the clavicle, and cannot be drawn downwards with the skin. The soft parts are allowed to glide up, and the cervical fascia is divided; if the interval between the Trapezius and Sternocleidomastoideus be insufficient, a portion of one or both may be divided. The external jugular vein will now be seen towards the medial side of the wound; this and the transverse scapular and transverse cervical veins which end in it should be held aside. If any large vein be at all in the way and exposed to injury, it should be tied in two places and divided. The transverse scapular artery should be avoided, and the Omohyoideus held aside if necessary. In the space beneath this muscle a deep layer of fascia and some connective tissue are divided, the lateral margin of the Scalenus anterior muscle felt for, and the finger being guided by it to the first rib, the pulsation of the subclavian artery will be felt as it passes over the rib. The sheath of the vessels having been opened, the aneurysm needle may then be passed around the artery from above downwards and medialwards so as to avoid including the lowest trunk of the brachial plexus which lies behind the artery on the first rib. If the clavicle be so raised by the tumour that the application of the ligature cannot be effected in this situation, the artery may be tied above the first rib, or even behind the Scalenus anterior.

The second part of the subclavian artery, the portion which rises highest in the neck, has been considered favourable for the application of the ligature when it is difficult to tie the artery in the third part of its course. There are, however, many objections to the operation in this situation. It is necessary to divide the Scalenus anterior, upon which lies the phrenic nerve, and at the medial side of which is situated the internal jugular vein; and a wound of either of these structures might lead to the most dangerous consequences. Again, the artery is in contact, below, with the pleura, which must also be avoided; and, lastly, the proximity of so many of its large branches arising medial to this point is a further objection to the operation. In cases, however, where the sac of an axillary aneurysm encroaches on the neck, it may be necessary to divide the lateral half or two-thirds of the Scalenus anterior, so as to place the ligature on the vessel at a greater distance from the sac. The operation is performed exactly in the same way as a ligature of the third portion, until the Scalenus anterior is exposed, when it is to be divided on a director (never to a greater extent than its lateral two-thirds), and it immediately retracts. This is therefore merely an extension of the operation for ligature of the third portion of the vessel.

In those cases of aneurysm of the axillary or subclavian artery which encroach upon the lateral portion of the Scalenus anterior to such an extent that a ligature cannot be applied in that situation, it may be deemed advisable, as a last resource, to tie the first portion of the subclavian artery. On the left side, this operation is almost impracticable; the great depth of the artery from the surface, its intimate relation with the pleura, and its close proximity to the thoracic duct and to so many important veins and nerves, present a series of difficulties which it is next to impossible to overcome. On the right side, the operation is practicable, the main difficulty being the smallness of the interval which usually exists between the commencement of the vessel and the origin of the nearest branch. The operation is essentially similar to that described on p. 603 for ligature of the innominate artery. The exact position of the vagus, recurrent, and phrenic nerves and the sympathetic trunk should be borne in mind, and the ligature should be applied near the origin of the vertebral, in order to afford as much room as possible for the formation of a coagulum between the ligature and the origin of the vessel. It should be remembered that the right subclavian artery is occasionally deeply placed in the first part of its course, when it arises from the left side of the aortic arch, and passes in such cases behind the œsophagus, or between it and the trachea.

Collateral Circulation.—After ligature of the third part of the subclavian artery, the collateral circulation is established mainly by three sets of vessels, thus described in a dissection:

1. A posterior set, consisting of the transverse scapular artery and the descending ramus of the transverse cervical branch of the subclavian, anastomosing with the subscapular from the axillary.

2. A medial set, produced by the connexion of the internal mammary on the one hand, with the arteria intercostalis suprema and the lateral thoracic and subscapular arteries on the other.

3. A middle or axillary set, consisting of a number of small vessels derived from branches of the subclavian and, passing through the axilla, terminating either in the axillary artery, or some of its branches. This last set presented most conspicuously the peculiar character of newly formed or, rather, dilated arteries, being excessively tortuous, and forming a complete plexus.

The chief agent in the restoration of the axillary artery below the aneurysm was the subscapular artery, which communicated freely with the internal mammary, transverse scapular, and descending ramus of the transverse cervical arteries of the subclavian, from all of which it received so great an influx of blood as to dilate it to three times its natural size.*

* *Guy's Hospital Reports*, vol. i. 1836. Case of axillary aneurysm, in which Aston Key had tied the subclavian artery at the lateral edge of the Scalenus anterior, twelve years previously.

When a ligature is applied to the first part of the subclavian artery, the collateral circulation is carried on by the following anastomoses: 1, between the superior and inferior thyreoids; 2, the two vertebrals; 3, the internal mammary with the inferior epigastric and the aortic intercostals; 4, the costocervical with the aortic intercostals; 5, the a. profunda cervicalis with the descending branch of the occipital; 6, the scapular branches of the thyreocervical trunk with the branches of the axillary; and 7, the thoracic branches of the axillary with the aortic intercostals.

Branches.—The branches of the subclavian artery are:

Vertebral.	Thyreocervical.
Internal mammary.	Costocervical.

On the left side of the neck all four branches generally rise from the first portion of the artery; on the right side the costocervical trunk usually springs from the second portion. On both sides, the first three branches originate close together at the medial border of the Scalenus anterior.

1. The **vertebral artery** (fig. 668) arises from the upper and posterior part of the first portion of the subclavian artery. It ascends through the foramina in the transverse processes of the upper six cervical vertebræ,* winds behind the superior articular process of the atlas, enters the skull through the foramen magnum, and, at the lower border of the pons, unites with the vessel of the opposite side to form the basilar artery.

Relations.—The vertebral artery may be divided into four parts. The *first part* runs upwards and backwards between the Longus colli and the Scalenus anterior and behind the common carotid artery. In front of it are the internal jugular and vertebral veins, and it is crossed by the inferior thyreoid artery; the left vertebral artery is crossed also by the thoracic duct. Behind it are the transverse process of the seventh cervical vertebra, the sympathetic trunk and its inferior cervical ganglion. The *second part* ascends through the foramina transversaria of the upper six cervical vertebræ, and is surrounded by a plexus of nerves derived from the inferior cervical sympathetic ganglion, and by a plexus of veins which unite to form the vertebral vein at the lower part of the neck. It lies in front of the trunks of the cervical nerves, and pursues an almost vertical course as far as the transverse process of the epistropheus, through which it runs upwards and lateralwards to the foramen transversarium of the atlas. The *third part* issues from the latter foramen on the medial side of the Rectus capitis lateralis, and curves backwards behind the superior articular process of the atlas, the anterior ramus of the first cervical nerve being on its medial side; it then lies in the groove on the upper surface of the posterior arch of the atlas, and enters the vertebral canal by passing beneath the lower arched border of the posterior atlanto-occipital membrane. This part of the artery is covered by the Semispinalis capitis and is contained in the *suboccipital triangle*, which is bounded by the Rectus capitis posterior major, the Obliquus superior, and the Obliquus inferior. The posterior division of the first cervical nerve lies between the artery and the posterior arch of the atlas. The *fourth part* pierces the dura mater and the arachnoid membrane, ascends in front of the roots of the hypoglossal nerve, and inclines medialwards to the front of the medulla oblongata, where, at the lower border of the pons, it unites with the vessel of the opposite side to form the basilar artery.

The branches of the vertebral artery may be divided into two sets—those given off in the neck, and those within the cranium.

Cervical branches.	*Cranial branches.*
Spinal.	Meningeal.
Muscular.	Posterior spinal.
	Anterior spinal.
	Posterior inferior cerebellar.
	Medullary.

Spinal branches enter the vertebral canal through the intervertebral foramina, and each divides into two branches. Of these, one passes along the roots of the nerves to supply the medulla spinalis and its membranes, anastomosing with the other arteries of the medulla spinalis; the other divides into an ascending and

* The vertebral artery sometimes enters the foramen in the transverse process of the fifth vertebra, and has been seen entering that of the seventh vertebra.

a descending branch, which unite with similar branches from the arteries above and below, so that two lateral anastomotic chains are formed on the posterior surfaces of the bodies of the vertebræ, near the attachment of the pedicles. From these anastomotic chains branches are supplied to the periosteum and the bodies of the vertebræ, and others communicate with similar branches from the opposite side; from these communications small twigs arise which join similar branches above and below, to form a central anastomotic chain on the posterior surfaces of the bodies of the vertebræ.

Muscular branches arise from the vertebral artery as it curves round the superior articular process of the atlas. They supply the deep muscles of the neck and anastomose with the occipital artery, and the ascending and deep cervical arteries.

One or two **meningeal branches** spring from the vertebral artery opposite the foramen magnum, ramify between the bone and dura mater in the cerebellar fossa, and supply the falx cerebelli.

The **posterior spinal artery** arises from the vertebral artery at the side of the medulla oblongata, but is frequently derived from the posterior cerebellar artery. It passes backwards, and then descends behind the posterior roots of the spinal nerves, and is reinforced by a succession of small branches, which arise from the vertebral, ascending cervical, intercostal and lumbar arteries, and enter the vertebral canal through the intervertebral foramina; by means of these it is continued to the lower part of the medulla spinalis, and to the cauda equina. Branches from the posterior spinal arteries form a free anastomosis round the posterior roots of the spinal nerves, and communicate with the vessels of the opposite side. Near its origin each posterior spinal artery gives off an ascending branch, which ends at the side of the fourth ventricle.

The **anterior spinal artery** is a small branch, which arises near the termination of the vertebral artery; it descends in front of the medulla oblongata and unites with its fellow of the opposite side near the level of the lower end of the olive of the medulla oblongata. The single trunk, thus formed, descends on the front of the medulla spinalis, and is reinforced by a succession of small branches which enter the vertebral canal through the intervertebral foramina; these branches are derived from the vertebral, the ascending cervical, intercostal, and lumbar arteries. They unite, by means of ascending and descending branches, to form a single anterior median artery, which extends as far as the lower part of the medulla spinalis, and is continued as a slender twig on the filum terminale. This vessel is placed in the pia mater along the anterior median fissure; it supplies that membrane, and the substance of the medulla spinalis, and sends off branches at its lower part to be distributed to the cauda equina. Branches pass from the anterior spinal arteries and from the beginning of the trunk formed by their union to the medulla oblongata.

The **posterior inferior cerebellar artery** (fig. 671) is the largest branch of the vertebral artery, but is not infrequently absent. It arises near, and winds backwards round, the lower end of the olive of the medulla oblongata; it then ascends behind the roots of the glossopharyngeal and vagus nerves to the under surface of the cerebellum, where it divides into a medial and a lateral branch. The medial branch runs backwards to the notch between the hemispheres of the cerebellum, while the lateral supplies the under surface of the hemisphere, as far as its lateral border, where it anastomoses with the anterior inferior cerebellar and the superior cerebellar branches of the basilar artery. Branches supply the medulla oblongata and the chorioid plexus of the fourth ventricle. A branch of this artery ascends between the biventral lobe and the tonsil of the cerebellum to supply the dentate nucleus of the cerebellum (Shellshear*).

The **medullary arteries** are several minute vessels which spring from the vertebral and its branches, and are distributed to the medulla oblongata.

The **basilar artery** (figs. 671, 674), so named from its position at the base of the skull, is formed by the junction of the two vertebral arteries; it extends from the lower to the upper border of the pons, and is contained within the cisterna pontis. It lies in a shallow, median groove on the ventral surface of the pons. It is placed between the two abducent nerves at the lower border, and between the two oculomotor nerves at the upper border, of the pons, where it divides into the two posterior cerebral arteries.

* J. L. Shellshear, *Lancet*, May 27th, 1922.

Its branches, on either side, are the following :

Pontine.	Anterior inferior cerebellar.
Internal auditory.	Superior cerebellar.
Posterior cerebral.	

The **pontine branches** are a number of small vessels which come off from the front and sides of the basilar artery, and supply the pons and adjacent parts of the brain.*

The **internal auditory artery,** a long slender branch, may arise from the lower part of the basilar artery, but is more often derived from the anterior inferior cerebellar artery; it accompanies the acoustic nerve through the internal acoustic meatus and is distributed to the internal ear.

The **anterior inferior cerebellar artery** arises from the lower part of the basilar artery. It runs backwards and lateralwards, usually ventral to the abducent nerve, and then between the pons and the facial and acoustic nerves, to the anterior part of the under surface of the cerebellum, where it anastomoses with the posterior inferior cerebellar branch of the vertebral artery. A few branches are supplied by the anterior inferior cerebellar artery to the lower and lateral parts of the pons, and sometimes to the upper part of the medulla oblongata.

The **superior cerebellar artery** arises near the termination of the basilar. It passes lateralwards immediately below the oculomotor nerve which separates it from the posterior cerebral artery, winds round the cerebral peduncle close to and below the trochlear nerve, and, arriving at the upper surface of the cerebellum, divides into branches which ramify in the pia mater and anastomose with those of inferior cerebellar arteries. Branches are given to the pons, the pineal body, the anterior medullary velum, and the tela chorioidea of the third ventricle.

The **posterior cerebral artery** (figs. 671, 672, 673), frequently double, is larger than the superior cerebellar artery, from which it is separated near its origin by the oculomotor nerve, and on the side of the mesencephalon by the trochlear nerve. Passing lateralwards, parallel to the superior cerebellar artery, and receiving the posterior communicating branch from the internal carotid artery, it winds round the cerebral peduncle, and reaches the tentorial surface of the cerebrum, where it breaks up into branches for the supply of the temporal and occipital lobes.

The branches of the posterior cerebral artery are divided into two sets, ganglionic and cortical :

Ganglionic	Posteromedial.	*Cortical*	Anterior temporal.
	Posterior chorioidal.		Posterior temporal.
	Posterolateral.		Calcarine.
			Parieto-occipital.

Ganglionic branches.—The *posteromedial ganglionic branches* (fig. 674) are several small arteries which arise at the commencement of the posterior cerebral artery; these with similar branches from the posterior communicating, pierce the posterior perforated substance, and supply the medial surfaces of the thalami and the walls of the third ventricle. The *posterior chorioidal branches* run forwards beneath the splenium of the corpus callosum, supply the tela chorioidea of the third ventricle, and end in the chorioid plexus of the lateral ventricle. The *posterolateral ganglionic branches* are small arteries which arise from the posterior cerebral artery after it has turned round the cerebral peduncle ; they supply a considerable portion of the thalamus.

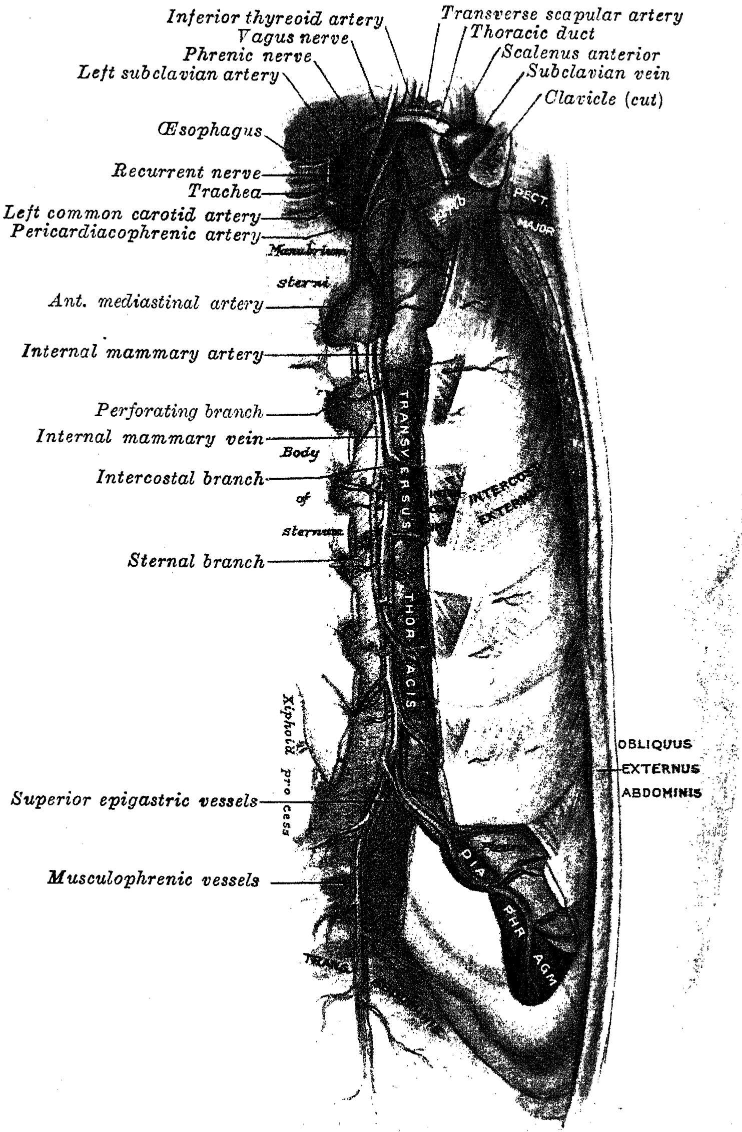
Cortical branches.—These are : the *anterior temporal,* distributed to the uncus and the anterior part of the fusiform gyrus ; the *posterior temporal,* to the fusiform and the inferior temporal gyri ; the *calcarine,* to the cuneus, gyrus lingualis, and the posterior part of the lateral surface of the occipital lobe ; and the *parieto-occipital,* to the cuneus and the præcuneus.

2. The **internal mammary artery** (fig. 676) arises from the under surface of the first portion of the subclavian artery, opposite the thyreocervical trunk. It descends behind the cartilages of the upper six ribs at a distance of 1·25 cm. from the lateral border of the sternum, and at the level of the sixth intercostal space divides into the *musculophrenic* and *superior epigastric* arteries.

* Consult an article on 'The arteries of the pons and medulla oblongata' by J. S. B. Stopford, *Journal of Anatomy,* vols. l., li.

Relations.—It runs at first downwards, forwards, and medialwards behind the sternal end of the clavicle, the internal jugular and innominate veins, and the first costal cartilage. As the artery enters the thorax, the phrenic nerve crosses it obliquely from the lateral to the medial side, the nerve usually passing in front of the artery. Below the first costal cartilage it descends almost vertically to its

FIG. 676.—The left internal mammary artery.



point of bifurcation. It is covered in front by the Pectoralis major, the cartilages of the upper six ribs and the intervening anterior intercostal membranes and Intercostales interni, and is crossed by the terminal portions of the upper six intercostal nerves. It is separated from the pleura, as far as the second or third costal cartilage, by a strong layer of fascia; below this level, by the Transversus thoracis. It is accompanied by a chain of lymph-glands and a pair of veins: about the level of the third costal cartilage the veins unite to form a single vessel, which runs medial to the artery and ends in the innominate vein.

The branches of the internal mammary artery are :

Pericardiacophrenic.	Sternal.	Musculophrenic.
Anterior mediastinal.	Intercostal.	Superior epigastric.
Pericardial.	Perforating.	

The **pericardiacophrenic artery** (a. comes nervi phrenici) is a long slender branch which accompanies the phrenic nerve, between the pleura and pericardium, to the Diaphragm; it gives branches to the pleura, pericardium and Diaphragm, and anastomoses with the musculophrenic and inferior phrenic arteries.

The **anterior mediastinal arteries** are small vessels, distributed to the areolar tissue and lymph-glands in the anterior mediastinal cavity, and to the remains of the thymus.

The **pericardial branches** supply the upper part of the anterior surface of the pericardium.

The **sternal branches** are distributed to the Transversus thoracis, and to the posterior surface of the sternum.

The anterior mediastinal, pericardial, and sternal branches, together with some twigs from the pericardiacophrenic, anastomose with branches from the intercostal and bronchial arteries, and form a **subpleural mediastinal plexus.**

The **intercostal branches** supply the upper five or six intercostal spaces. Two in number in each space, they pass lateralwards, one lying near the lower margin of the rib above, and the other near the upper margin of the rib below, and anastomose with the intercostal arteries from the aorta. They are at first situated between the pleura and the Intercostales interni, and then between the Intercostales interni et externi. They supply the Intercostales and send branches through the Intercostales externi to the Pectorales and the mamma.

The **perforating branches** emerge through the upper five or six intercostal spaces. They pierce the Pectoralis major, and curving lateralwards, supply that muscle and the skin. Those of the second, third, and fourth spaces give branches to the mamma, and during lactation are of large size.

The **musculophrenic artery** is directed obliquely downwards and lateralwards, behind the cartilages of the false ribs; it perforates the Diaphragm at the eighth or ninth costal cartilage, and ends, considerably reduced in size, opposite the last intercostal space. It gives off intercostal branches to the seventh, eighth, and ninth intercostal spaces; these diminish in size as the spaces decrease in length, and are distributed in a manner similar to the intercostals from the internal mammary. The musculophrenic also gives branches to the lower part of the pericardium, the Diaphragm, and the abdominal muscles.

The **superior epigastric artery** descends through the interval between the costal and xiphoid origins of the Diaphragm, and enters the sheath of the Rectus abdominis, at first lying behind the muscle, and then perforating and supplying it, and anastomosing with the inferior epigastric artery from the external iliac. Branches perforate the sheath of the Rectus, and supply the muscles and skin of the abdomen, and a small branch passes in front of the xiphoid process and anastomoses with the artery of the opposite side. The superior epigastric artery also gives some twigs to the Diaphragm, while from the artery of the right side small branches extend into the falciform ligament of the liver and anastomose with the hepatic artery.

Applied Anatomy.—The internal mammary artery is liable to be wounded in stabs of the chest-wall and in the operation of paracentesis pericardii (p. 577). It is most easily reached by a transverse incision in the second intercostal space.

3. The **thyreocervical trunk** (thyreoid axis) (fig. 675), a short thick trunk, arises from the front of the first portion of the subclavian artery, close to the medial border of the Scalenus anterior, and divides almost immediately into three branches, the *inferior thyreoid*, *transverse scapular*, and *transverse cervical*.

The **inferior thyreoid artery** runs upwards in front of the vertebral artery and Longus colli; it then turns medialwards behind the carotid sheath and its contents, and also behind the sympathetic trunk, the middle cervical ganglion of which rests upon the vessel; it finally descends to the lower border of the lateral lobe of the thyreoid gland. At a little distance below the gland the inferior thyreoid artery usually passes behind the recurrent nerve, but when the gland is reached the nerve is often behind the branches of the artery.*

* F. G. Parsons, *Journal of Anatomy*, vol. liv. p. 172.

The branches of the inferior thyreoid are :

Muscular.	Inferior laryngeal.	Œsophageal.
Ascending cervical.	Tracheal.	Glandular.

The **muscular branches** supply the depressors of the hyoid bone, and the Longus colli, Scalenus anterior, and Constrictor pharyngis inferior.

The **ascending cervical artery** is a small branch which arises from the inferior thyreoid artery as that vessel is passing behind the carotid sheath ; it ascends on the anterior tubercles of the transverse processes of the cervical vertebræ in the interval between the Scalenus anterior and Longus capitis. It gives twigs to the muscles of the neck, and sends one or two spinal branches into the vertebral canal through the intervertebral foramina to be distributed to the medulla spinalis and its membranes, and to the bodies of the vertebræ, in the same manner as the spinal branches from the vertebral artery. It anastomoses with the vertebral, ascending pharyngeal and occipital arteries.

The **inferior laryngeal artery** ascends upon the trachea in company with the recurrent nerve ; it enters the larynx under the lower border of the Constrictor pharyngis inferior, and supplies its muscles and mucous membrane, anastomosing with the artery from the opposite side, and with the superior laryngeal branch of the superior thyreoid artery.

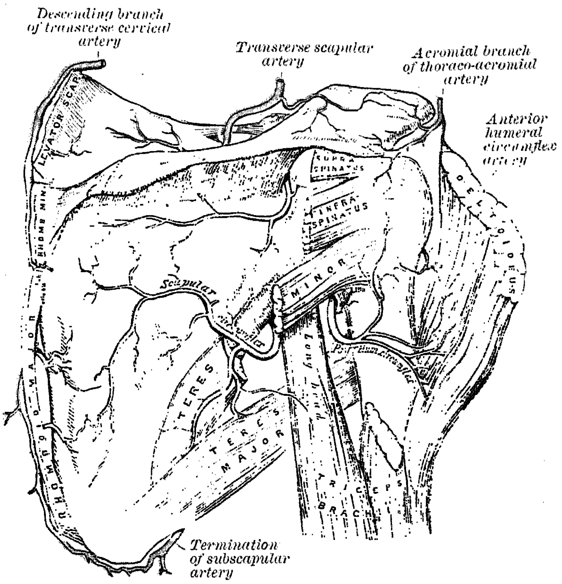
The **tracheal branches** are distributed to the trachea, and anastomose below with the bronchial arteries.

The **œsophageal branches** supply the œsophagus, and anastomose with the œsophageal branches of the thoracic aorta.

The **glandular branches** consist of an inferior and an ascending branch ; they are distributed to the posterior and inferior parts of the thyreoid gland, and anastomose with the superior thyreoid artery and with the opposite inferior thyreoid artery ; the ascending branch supplies the superior parathyreoid gland.

The **transverse scapular artery** (suprascapular artery) (fig. 675) passes at first downwards and lateralwards across the Scalenus anterior and phrenic nerve, under cover of the Sternocleidomastoideus ; it then crosses the subclavian artery and the brachial plexus, and runs behind and parallel with the clavicle and Subclavius, and beneath the inferior belly of the Omohyoideus, to the superior border of the scapula ; here it passes over (occasionally under) the superior transverse ligament which separates it from the suprascapular nerve, and enters the supraspinatous fossa (fig. 677). In this situation it lies on the bone, and supplies branches to the Supraspinatus. It then descends behind the neck of the scapula, through the great scapular notch and beneath the inferior transverse ligament, to reach the deep surface of the Infraspinatus, where it anastomoses with the scapular circumflex artery and the descending branch of the transverse cervical artery. Besides distributing branches to the Sternocleidomastoideus, Subclavius, and neighbouring muscles, it gives off a *suprasternal branch*, which crosses over the sternal end of the clavicle to the skin of the upper part of the chest ; and an *acromial branch*, which pierces the Trapezius and supplies the skin over the acromion, anastomosing with the thoraco-acromial artery. As the transverse scapular artery passes over the superior transverse ligament of the scapula, it sends a branch into the subscapular fossa, where it ramifies beneath the Subscapularis, and anastomoses with the subscapular artery and with the descending branch of the transverse cervical artery. The transverse scapular artery also sends articular branches to the

Fig. 677.—The right scapular and circumflex arteries.



acromioclavicular and shoulder-joints, and nutrient arteries to the clavicle and scapula. Occasionally the transverse scapular artery arises from the third part of the subclavian artery.

The **transverse cervical artery** (a. transversa colli) (fig 675) lies at a higher level than the transverse scapular artery; it crosses in front of the phrenic nerve and the Scaleni, and in front of or between the divisions of the brachial plexus, and is covered by the Platysma and Sternocleidomastoideus. It passes behind the Omohyoideus and runs transversely above the inferior belly of that muscle, to the anterior margin of the Levator scapulæ, where it divides into an ascending and a descending branch.

The *ascending branch* (superficial cervical artery) ascends beneath the anterior part of the Trapezius, distributing branches to it and to the neighbouring muscles and lymph-glands in the neck, and anastomosing with the superficial branch of the ramus descendens of the occipital artery.

The *descending branch* (posterior scapular artery) (fig. 677) passes beneath the Levator scapulæ to the medial angle of the scapula, and then descends under cover of the Rhomboidei along the vertebral border of the scapula as far as the inferior angle of the bone. It supplies branches to the Rhomboidei, Latissimus dorsi and Trapezius, and anastomoses with the transverse scapular and subscapular arteries, and with the posterior branches of some of the intercostal arteries.

Peculiarities.—Frequently the ascending branch (superficial cervical artery) arises directly from the thyreocervical trunk, and the descending branch (posterior scapular artery) from the third, more rarely from the second, part of the subclavian.

4. The **costocervical artery** (superior intercostal artery) (fig. 668) arises from the posterior aspect of the second part of the subclavian artery on the right side, but from the first part of the artery on the left side. It arches backwards above the cupula of the pleura to the neck of the first rib, and divides into the arteria intercostalis suprema and the arteria cervicalis profunda.

The **arteria intercostalis suprema** descends behind the pleura in front of the necks of the first and second ribs, and anastomoses with the first aortic intercostal artery. As it crosses the neck of the first rib it is medial to the anterior division of the first thoracic nerve, and lateral to the first thoracic ganglion of the sympathetic trunk. In the first intercostal space, it gives off a branch which is distributed in a manner similar to the distribution of the aortic intercostals. The branch for the second intercostal space usually joins with one from the first aortic intercostal artery; this branch is not constant, but is more commonly found on the right side; when absent, its place is supplied by an intercostal branch from the aorta.

The **arteria cervicalis profunda** arises, in most cases, from the costocervical trunk, and is analogous to the posterior branch of an aortic intercostal artery: occasionally it is a separate branch from the subclavian artery. Passing backwards above the eighth cervical nerve and between the transverse process of the seventh cervical vertebra and the neck of the first rib, it ascends on the back of the neck, between the Semispinales capitis et colli, as high as the second cervical vertebra, supplying the adjacent muscles, and anastomosing with the deep division of the ramus descendens of the occipital artery (p. 615) and with branches of the vertebral artery. It gives off a spinal twig which enters the vertebral canal through the foramen between the seventh cervical and first thoracic vertebræ.

The Axilla

The **axilla** is a pyramidal space, situated between the upper part of the lateral wall of the chest and the upper part of the medial side of the arm.

The *apex* of the axilla is directed upwards towards the root of the neck, and corresponds to the interval between the outer border of the first rib, the superior border of the scapula, and the posterior surface of the clavicle; through it the axillary vessels and nerves enter the space from the neck. The *base*, directed downwards, is broad at the chest but narrow and pointed at the arm; it is formed by the skin and a thick layer of fascia, the *axillary fascia*, extending between the lower border of the Pectoralis major in front, and the lower border of the Latissimus dorsi behind. The *anterior wall* is formed by the Pectorales major et minor, the former covering the whole of this wall,

the latter only its central part. The space between the upper border of the Pectoralis minor and the clavicle is occupied by the coracoclavicular fascia (costocoracoid membrane). The *posterior wall* is formed by the Subscapularis above, the Teres major and Latissimus dorsi below. On the *medial side* are the first four ribs with their corresponding Intercostales, and the upper part of the Serratus anterior. On the *lateral side*, where the anterior and posterior walls converge, the space is narrow, and bounded by the humerus, the Coracobrachialis, and the Biceps brachii.

The axilla contains the axillary vessels, the infraclavicular part of the brachial plexus of nerves, with its branches, the lateral branches of some of the intercostal nerves, and a large number of lymph-glands, together with a quantity of fat and loose areolar tissue. The axillary vessels and the brachial plexus of nerves run from the apex to the base along the lateral wall of the axilla; they are placed nearer to the anterior than to the posterior wall, the axillary vein lying to the thoracic side of the axillary artery and partially concealing it. The thoracic branches of the axillary artery are in contact with the Pectorales, and along the lower margin of the Pectoralis minor the lateral thoracic artery passes to the side of the thorax. The subscapular vessels and nerves descend on the posterior wall in contact with the lower margin of the Subscapularis; the scapular circumflex vessels wind round the axillary border of the scapula, and the posterior humeral circumflex vessels and the axillary nerve curve backwards close to the neck of the humerus. No vessel of any importance exists along the medial or thoracic side, the upper part of the space being crossed merely by a few small branches from the highest thoracic artery. The long thoracic nerve descends on the surface of the Serratus anterior, to which it is distributed; and the intercostobrachial nerve perforates the upper and anterior part of this wall, and passes across the axilla to the medial side of the arm.

The position and arrangement of the lymph-glands are described on pp. 758 to 760.

Applied Anatomy.—The axilla is a space of considerable surgical importance. Its vessels and nerves may be the seat of injury or disease: its lymph-glands may require removal; its loose connective tissue may be readily infiltrated with blood or inflammatory exudation. Moreover, its base is covered by thin skin, which is well supplied with sebaceous and sweat glands, and is frequently the seat of small abscesses and boils.

Penetrating wounds in the axilla are sometimes accompanied by extensive hæmorrhage, either from wound of the main vessels, or of one of the large branches of the axillary artery, e.g. the lateral thoracic or the subscapular. Where the blood cannot find an easy exit it collects in the space and forms a large swelling which projects in the floor of the axilla and also bulges forwards the Pectoralis major. The treatment consists in freely opening up the cavity, searching for and securing the bleeding vessel.

When suppuration occurs in the axilla, the arrangement of the fasciæ plays a very important part in the direction which the pus takes. As described on p. 498, the coracoclavicular fascia, after covering the space between the clavicle and the upper border of the Pectoralis minor, splits to enclose this muscle, and at its lower border is incorporated with the axillary fascia at the anterior fold of the axilla. Suppuration may take place either superficial to or beneath this layer of fascia; that is, either between the Pectorales or behind the Pectoralis minor; in the former case, the abscess would point either at the border of the anterior axillary fold, or in the groove between the Deltoideus and the Pectoralis major; in the latter, the pus would have a tendency to surround the vessels and nerves, and ascend into the neck, that being the direction in which there is least resistance. Its progress towards the surface is prevented by the axillary fascia; its progress backwards, by the insertion of the Serratus anterior; forwards, by the coracoclavicular fascia; medialwards, by the wall of the thorax; and lateralwards, by the upper limb. The pus in these cases, after extending into the neck, has been known to spread through the superior opening of the thorax into the mediastinal cavity. Instances have been recorded where the pus found its way along the vessels into the arm.

When opening an axillary abscess, the knife should be entered in the floor of the axilla, midway between the anterior and posterior margins and near the thoracic side of the space so as to avoid the lateral thoracic, subscapular, and axillary vessels which are in contact respectively with the anterior, posterior and lateral walls of the axilla. After an incision has been made through the skin and fascia, it is well to use a director and dressing forceps in the manner directed by Hilton.

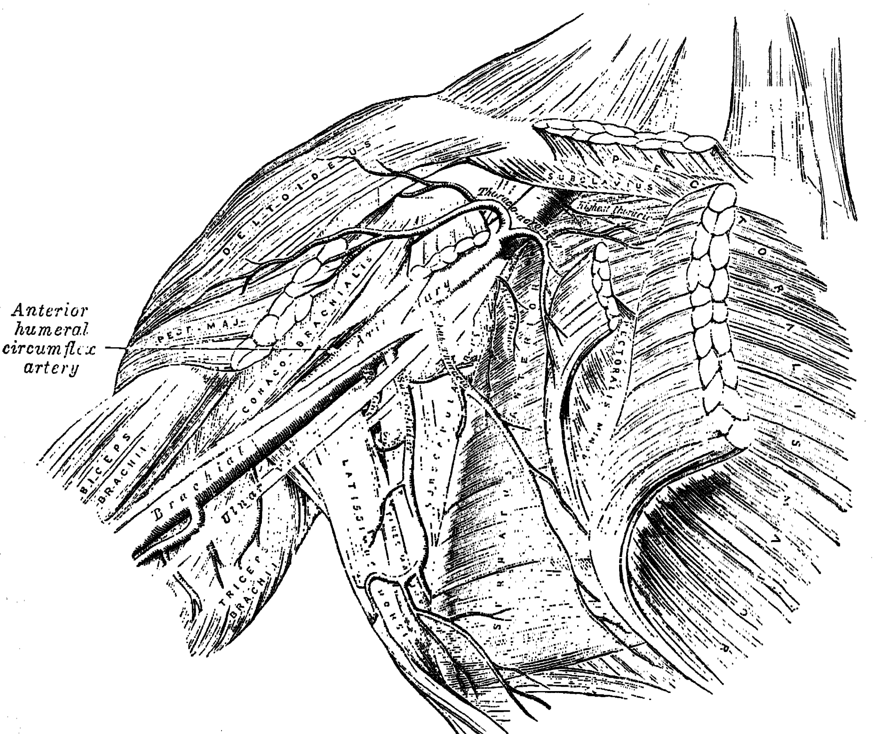
The relations of the vessels and nerves in the several parts of the axilla are important, for it is the universal plan to remove the lymph-glands from the axilla in operating for cancer of the breast. In performing such an operation, it is necessary to proceed with

much caution in the direction of the lateral wall and apex of the space, as here the axillary vessels are in danger of being wounded. The thoracodorsal nerve to the Latissimus dorsi and the long thoracic nerve to the Serratus anterior must be defined and isolated. In clearing out the axilla, the axillary vein should first be defined and traced up to the apex of the space by means of a director. In order to do this the Pectoralis major, together with the whole of the Pectoralis minor, must be divided and turned aside, by which means the surgeon is enabled to clear out the axillary cavity more thoroughly. When the apex of the space is reached all the fat and the lymph-glands must be carefully removed and the whole axilla cleared by separating the tissues from above downwards from the vessels, and from the medial and posterior walls, so that when the proceeding is completed the axilla is emptied of all its contents except the main vessels and nerves.

The Axillary Artery (fig. 678)

The **axillary artery**, the continuation of the subclavian artery, begins at the outer border of the first rib, and ends at the lower border of the Teres major, beyond which the artery takes the name of brachial. Its direction varies with the position of the limb: thus the vessel is nearly straight when

Fig. 678.—The right axillary artery and its branches.



the arm is directed at right angles with the trunk, concave upwards when the arm is elevated above this, and convex upwards and lateralwards when the arm lies by the side of the trunk. The first part of the artery is deeply situated, but its terminal part is superficial and is covered only by the skin and fasciæ. The Pectoralis minor crosses the vessel and divides it into three portions; the first part is proximal to, the second behind, and the third distal to the muscle.

Relations of the first part.—*In front* of the first part of the axillary artery are the skin, superficial fascia, Platysma, supraclavicular nerves from the cervical plexus, deep fascia, clavicular fibres of the Pectoralis major, and the coracoclavicular fascia. This part of the artery is crossed by the lateral anterior thoracic nerve, and by the thoraco-acromial and cephalic veins. *Behind* the artery are the first intercostal space and Intercostalis externus, the first and second digitations of the

Serratus anterior, the long thoracic and medial anterior thoracic nerves, and the medial cord of the brachial plexus. On the *lateral side* of the artery are the lateral and posterior cords of the brachial plexus; on the *medial side* is the axillary vein which overlaps the artery. The first part of the artery is enclosed, together with the axillary vein and the brachial plexus, in a fibrous sheath, the *axillary sheath*, continuous above with the deep cervical fascia.

Relations of the second part.—In front of the second part of the axillary artery are the skin, superficial and deep fascia, and the Pectorales major et minor; *behind* it are the posterior cord of the brachial plexus and some areolar tissue which intervene between it and the Subscapularis; on the *medial side* is the axillary vein, separated from the artery by the medial cord of the brachial plexus and the medial anterior thoracic nerve; on the *lateral side* is the lateral cord of the brachial plexus. The cords of the brachial plexus thus surround the second part of the artery on three sides, and separate it from direct contact with the vein and adjacent muscles.

Relations of the third part.—The third part of the axillary artery extends from the lower border of the Pectoralis minor to the lower border of the Teres major. Its upper part is covered *in front* by the lower part of the Pectoralis major; its lower part by the skin and fasciæ only. *Behind* it are the lower part of the Subscapularis and the tendons of the Latissimus dorsi and Teres major. On its *lateral side* is the Coracobrachialis, and on its *medial side*, the axillary vein. The nerves of the brachial plexus bear the following relations to this part of the artery; on the *lateral side* are the lateral head and the trunk of the median, and, for a short distance the musculocutaneous; on the *medial side* are the medial antibrachial cutaneous, ulnar, and medial brachial cutaneous nerves. The medial antibrachial cutaneous nerve lies between the artery and vein anteriorly, and the ulnar nerve between the axillary artery and vein posteriorly; the medial brachial cutaneous nerve is on the medial side of the vein; *in front* is the medial head of the median nerve, and *behind*, the radial and axillary nerves, the latter only as far as the lower border of the Subscapularis.

Applied Anatomy.—Compression of the axillary artery may be required in the removal of tumours, or in amputation of the upper part of the arm. The only situation in which compression can be effectually made is in the lower part of its course; by pressing the artery against the humerus in this situation, the circulation may be effectually arrested.

With the exception of the popliteal, the axillary artery is perhaps more frequently lacerated than any other artery in the body by violent movements, particularly in those cases where its coats are diseased. It has occasionally been ruptured in attempts to reduce old dislocations of the shoulder-joint, especially where the artery has become fixed to the capsule of the joint. Aneurysm of the axillary artery sometimes occurs and is often traumatic in its origin.

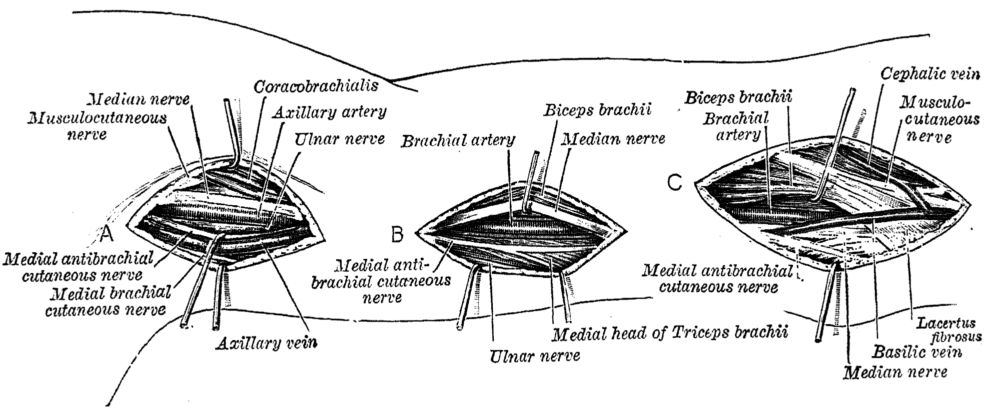
Ligature of the axillary artery may be required in cases of aneurysm of the upper part of the brachial, or as a distal operation for aneurysm of the subclavian.

Ligature of the *third part* of the axillary artery is easy, and may be performed as follows (fig. 679, A): The arm is drawn from the side, the hand supinated, and an incision about 5 cm. long made through the skin of the floor of the axilla, a little nearer to the anterior than to the posterior fold of the axilla. After dissecting through the areolar tissue and fascia, the median nerve and axillary vein are exposed; these are retracted and, the elbow being bent so as relax the structures, the ligature is applied. This portion of the artery is occasionally crossed by a muscular slip, the *axillary arch* (p. 495), derived from the Latissimus dorsi.

The *first portion* of the axillary artery may be tied in cases of aneurysm encroaching so far upwards that a ligature cannot be applied to the lower part of the artery. Its performance is attended with much difficulty and danger. The student will remark that, in this situation, it would be necessary to divide a thick muscle, and, after incising the coracoclavicular fascia, the artery would be exposed at the bottom of a more or less deep space, with the cephalic and axillary veins in such relation with it as must render the application of a ligature to it particularly hazardous. Under such circumstances, it is an easier and, at the same time, a more advisable operation, to tie the third part of the subclavian artery. The first part of the axillary artery can be best secured by a curved incision with the convexity downwards from a point 1·25 cm. lateral to the sternoclavicular joint to a point 1·25 cm. on the medial side of the coracoid process. The limb is to be well abducted, and the incision carried through the superficial structures, care being taken of the cephalic vein at the lateral end of the incision. The clavicular origin of the Pectoralis major is then divided in the whole extent of the wound. The arm is now brought to the side, and the upper edge of the Pectoralis minor defined and drawn downwards. The coracoclavicular fascia is divided, and the axillary sheath exposed; this is to be opened with especial care on account of the vein overlapping the artery. The needle should be passed from below, so as to avoid wounding the vein.

The *second portion* of the axillary artery may be tied through an incision begun over the junction of the middle with the lateral one-third of the clavicle, and carried downwards between the Deltoideus and the clavicular part of the Pectoralis major as far as the junction of the anterior fold of the axilla with the upper arm. These two muscles are separated and the Pectoralis minor divided. The artery must be clearly defined, as it is surrounded by the large nerve-trunks.

Fig. 679.—Dissections to show (A) the third part of the axillary artery, (B) the brachial artery at the middle of the arm, and (C) the brachial artery at the lower part of the arm.



Collateral Circulation.—If the axillary artery be tied above the origin of the thoraco-acromial artery, the collateral circulation will be carried on by the same branches as after the ligature of the third part of the subclavian (p. 635), if at a lower point, between the thoraco-acromial and the subscapular arteries, the latter vessel, by its free anastomoses with the transverse scapular and transverse cervical arteries, will become the chief agent in carrying on the circulation; the lateral thoracic artery, if it be below the ligature, will materially contribute by its anastomoses with the intercostal and internal mammary arteries. If the ligature be applied below the origin of the subscapular artery, it will most probably also be below the origins of the two humeral circumflex arteries; the chief agents in restoring the circulation will then be the subscapular and the two humeral circumflex arteries anastomosing with the arteria profunda brachii.

The branches of the axillary artery are:

From first part 1. Highest thoracic. *From second part* { 2. Thoraco-acromial. 3. Lateral thoracic. }

From third part { 4. Subscapular. 5. Anterior humeral circumflex. 6. Posterior humeral circumflex. }

1. The **highest thoracic artery** (superior thoracic artery) (fig. 678) is a small vessel, which arises from the axillary artery near the lower border of the Subclavius muscle, but may take origin from the thoraco-acromial artery. Running forwards and medialwards along the upper border of the Pectoralis minor, it passes between it and the Pectoralis major to the side of the chest. It supplies branches to these muscles, and to the thoracic wall, and anastomoses with the internal mammary and intercostal arteries.

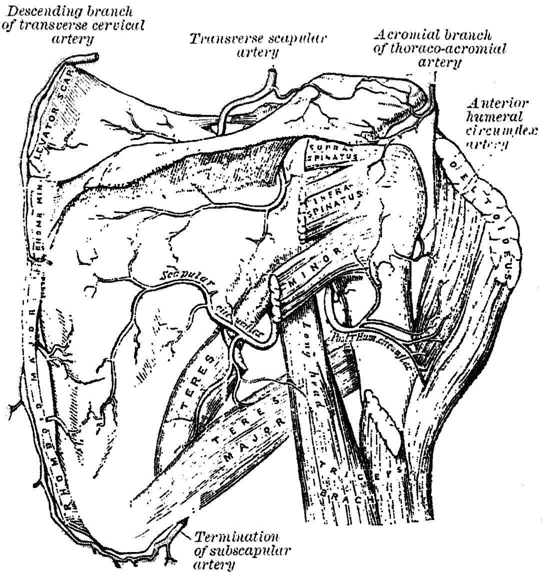
2. The **thoraco-acromial artery** (thoracic axis) (fig. 678) is a short trunk which arises from the front of the axillary artery, its origin being overlapped by the upper edge of the Pectoralis minor. Passing forwards at the upper border of this muscle, it pierces the coracoclavicular fascia and divides into four branches—pectoral, acromial, clavicular, and deltoid. The *pectoral branch* descends between the two Pectorales, and is distributed to them and to the mamma, anastomosing with the intercostal branches of the internal mammary artery and with the lateral thoracic artery. The *acromial branch* runs lateralwards over the coracoid process and under the Deltoideus, to which it gives branches; it then pierces that muscle and ends on the acromion, where it anastomoses with branches of the transverse scapular, thoraco-acromial, and posterior humeral circumflex arteries.

The *clavicular branch* runs upwards and medialwards between the clavicular part of the Pectoralis major and the coracoclavicular fascia ; it gives branches to the sternoclavicular joint, and to the Subclavius. The *deltoid* or *humeral branch* often arises with the acromial branch ; it crosses over the Pectoralis minor and runs with the cephalic vein between the Pectoralis major and Deltoideus, giving branches to both muscles.

3. The **lateral thoracic artery** (long thoracic artery) (fig. 678) follows the lower border of the Pectoralis minor to the side of the chest, supplies the Serratus anterior and the Pectorales, and sends branches to the axillary lymph-glands, and to the Subscapularis ; it anastomoses with the internal mammary, subscapular, and intercostal arteries, and with the pectoral branch of the thoraco-acromial artery. In the female, the lateral thoracic artery is large, and gives off an *external mammary branch* which turns round the free edge of the Pectoralis major and supplies the mamma.

4. The **subscapular artery** (fig. 678), the largest branch of the axillary artery, arises at the lower border of the Subscapularis, which it follows to the inferior angle of the scapula, where it anastomoses with the lateral thoracic and intercostal arteries and with the descending branch of the transverse cervical artery, and ends in the neighbouring muscles and adjacent part of the chest-wall. In the lower part of its course it is accompanied by the thoracodorsal nerve ; about 4 cm. from its origin it gives off the *scapular circumflex artery.*

FIG. 680.—The right scapular and circumflex arteries.



The **scapular circumflex artery** (arteria dorsalis scapulæ) is generally larger than the continuation of the subscapular. It curves round the axillary border of the scapula, traversing the triangular space between the Subscapularis above, the Teres major below, and the long head of the Triceps laterally (fig. 680) ; it enters the infraspinatous fossa under cover of the Teres minor, and anastomoses with the transverse scapular artery and the descending branch of the transverse cervical artery. It gives off two branches : one (*infrascapular*) enters the subscapular fossa beneath the Subscapularis, which it supplies, and anastomoses with the transverse scapular artery and the descending branch of the transverse cervical artery ; the other is continued along the axillary border of the scapula, between the Teres major and the Teres minor, and at the dorsal surface of the inferior angle anastomoses with the descending branch of the transverse cervical artery. In addition to these, small branches are distributed to the posterior part of the Deltoideus and the long head of the Triceps brachii, anastomosing with an ascending branch of the arteria profunda brachii.

5. The **anterior humeral circumflex artery** (fig. 680), a small artery, arises from the lateral side of the axillary artery at the lower border of the Subscapularis. It runs horizontally, beneath the Coracobrachialis and short head of the Biceps brachii, in front of the neck of the humerus. On reaching the intertubercular sulcus, it gives off a branch which ascends in the sulcus to supply the head of the humerus and the shoulder-joint. The trunk of the vessel is then continued onwards beneath the long head of the Biceps brachii and the Deltoideus, and anastomoses with the posterior humeral circumflex artery.

6. The **posterior humeral circumflex artery** (fig. 680), considerably larger than the anterior, arises from the axillary artery at the lower border of the Subscapularis,

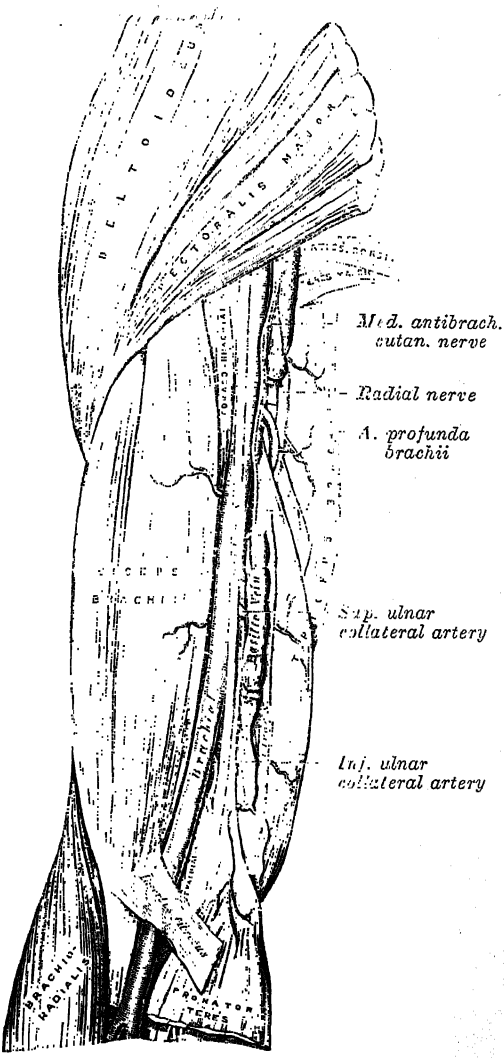
and runs backwards with the axillary nerve through the quadrangular space bounded by the Subscapularis, the Teres minor and the capsule of the shoulder-joint above, the Teres major below, the long head of the Triceps brachii medially, and the surgical neck of the humerus laterally. It winds round the neck of the humerus and distributes branches to the shoulder-joint, the Deltoideus, the Teretes major et minor, and the long and lateral heads of the Triceps brachii. It anastomoses with the anterior humeral circumflex, transverse scapular, thoraco-acromial, and profunda brachii arteries.

Peculiarities.—The branches of the axillary artery vary considerably in different subjects. One, named *alar thoracic*, and frequently derived from the second part of the artery, is distributed to the fat and the lymph-glands in the axilla. Occasionally the subscapular, humeral circumflex, and profunda arteries arise from a common trunk, and when this occurs the branches of the brachial plexus surround this trunk instead of the main vessel. Sometimes the axillary artery divides into the radial and ulnar arteries, and occasionally it gives origin to the volar interosseous artery of the forearm.

The Brachial Artery (figs. 681, 682, 683)

The **brachial artery** is a continuation of the axillary artery. It begins at the distal border of the tendon of the Teres major, runs down the arm, and ends about 1 cm. below the elbow-joint by dividing into radial and ulnar arteries. At first it lies on the medial side of the humerus, but, gradually passing to the front of the arm, is placed midway between the humeral epicondyles at the elbow.

Fig. 681.—The brachial artery.



Relations.—The artery is superficial throughout its entire extent, being covered with the skin and the superficial and deep fasciæ; the lacertus fibrosus (bicipital fascia) lies in front of it opposite the elbow and separates it from the median cubital vein; the median nerve crosses the artery from the lateral to the medial side opposite the insertion of the Coracobrachialis. *Posteriorly*, it is separated above from the long head of the Triceps brachii by the radial nerve and arteria profunda brachii. It then lies successively on the medial head of the Triceps brachii, the insertion of the Coracobrachialis, and the Brachialis. *Laterally*, it is in relation above with the median nerve and the Coracobrachialis, below with the Biceps brachii, the two muscles overlapping the artery to some extent *Medially*, its upper half is in relation with the medial antibrachial cutaneous and ulnar nerves, its lower half with the median nerve. The basilic vein lies on its medial side, but is separated from it in the lower part of the arm by the deep fascia. The artery is closely accompanied by two venæ comitantes which are connected at intervals by short transverse branches.

The Cubital Fossa

At the bend of the elbow the brachial artery sinks deeply into a triangular interval, the *cubital fossa*. The base of the triangle is represented by a line connecting the two humeral epicondyles ; the sides are formed by the medial edge of the Brachioradialis and the lateral margin of the Pronator teres ; the floor consists of the Brachialis and Supinator. This fossa contains the tendon of the Biceps brachii, the terminal part of the brachial artery, and its accompanying veins, the origins of the radial and ulnar arteries, and parts of the median and radial nerves. The brachial artery occupies the middle of the fossa, and divides opposite the neck of the radius into the radial and ulnar arteries ; it is covered, *in front*, by the skin, the superficial fascia, and the median cubital vein, the last being separated from the artery by the lacertus fibrosus. *Behind* it is the Brachialis, which separates it from the elbow-joint. The median nerve lies close to the medial side of the artery above, but is separated from it below by the ulnar head of the Pronator teres. The tendon of the Biceps brachii is lateral to the artery ; the radial nerve rests upon the Supinator, and is concealed by the Brachioradialis.

Peculiarities.—The brachial artery, accompanied by the median nerve, may leave the medial border of the Biceps brachii, and descend towards the medial epicondyle of the humerus; in such cases it usually passes behind the *supracondylar process* of the humerus, from which a fibrous arch is in most cases thrown over the artery; it then runs beneath or through the substance of the Pronator teres, to the bend of the elbow. This variation bears considerable analogy with the normal condition of the artery in some of the carnivora, and has been referred to in the description of the humerus (p. 284*). Occasionally, the upper part of the artery splits into two trunks which reunite. Frequently it divides at a higher level than usual, and the vessels concerned in this high division are three: viz. radial, ulnar, and interosseous arteries. Most frequently the radial is given off high up, the other limb of the division consisting of the ulnar and interosseous ; in some instances the ulnar originates above the ordinary level, and the radial and interosseous form the other limb of the division; occasionally the interosseous arises high up.

Sometimes long slender vessels, termed *vasa aberrantia*, connect the brachial or the axillary artery with one or other of the arteries of the forearm. These vessels usually join the radial.

The brachial artery is occasionally concealed in some part of its course, by muscular or tendinous slips derived from the Coracobrachialis, Biceps brachii, Brachialis, or Pronator teres.

Applied Anatomy.—In spite of the fact that the brachial artery is very superficial and but little protected by surrounding parts, it is seldom wounded. This, no doubt, is due to its situation on the medial side of the arm, which is little exposed to injury.

Compression of the brachial artery is required in cases of amputation and some other operations in the arm and forearm, and may be effected in almost any part of the course of the artery. If pressure be made in the upper part of the arm, it should be directed lateralwards; if in the lower part, backwards, as the artery lies on the medial side of the humerus above, and in front of it below. The most favourable situation is about the middle of the arm, where the artery lies on the tendon of the Coracobrachialis on the medial surface of the humerus.

Ligature of the brachial artery may be required in cases of wound of the vessel, and in some cases of wound of the volar arch where an extensive dissection might be required to expose the bleeding point in the hand. It is also sometimes necessary in cases of aneurysm of the brachial, radial, ulnar, or interosseous arteries. The artery may be secured in any part of its course. The chief guides in determining its position are the surface markings produced by the medial margins of the Coracobrachialis and Biceps brachii, and the known course of the vessel; its pulsation should be carefully felt for before any operation is performed, as the vessel occasionally deviates from its usual position. It is essential in applying a ligature to this vessel that the arm should be held away from the side of the body, and supported only from the elbow, for if the arm be allowed to rest on any firm structure the Triceps brachii is pressed forwards and overlaps the vessel, thus making the operation much more difficult.

In the upper third of the arm the brachial artery may be exposed in the following manner. The patient being placed supine, the limb should be raised from the side, and the hand supinated. An incision about 5 cm. in length is made on the medial side of the Coracobrachialis (fig. 682), and the subjacent fascia cautiously divided, so as to avoid wounding the medial antibrachial cutaneous nerve or basilic vein, as the latter sometimes runs on the surface of the artery as high as the axilla. The fascia having been divided, it should be remembered that the ulnar nerve and the medial antibrachial cutaneous nerve lie on the medial side of the artery, the median nerve on the lateral side

but occasionally superficial to the artery in this situation, and that the venæ comitantes are also in relation with the vessel, one on either side. These being carefully separated,

FIG. 682.—A transverse section through the arm at the junction of the proximal with the intermediate one-third of the humerus.

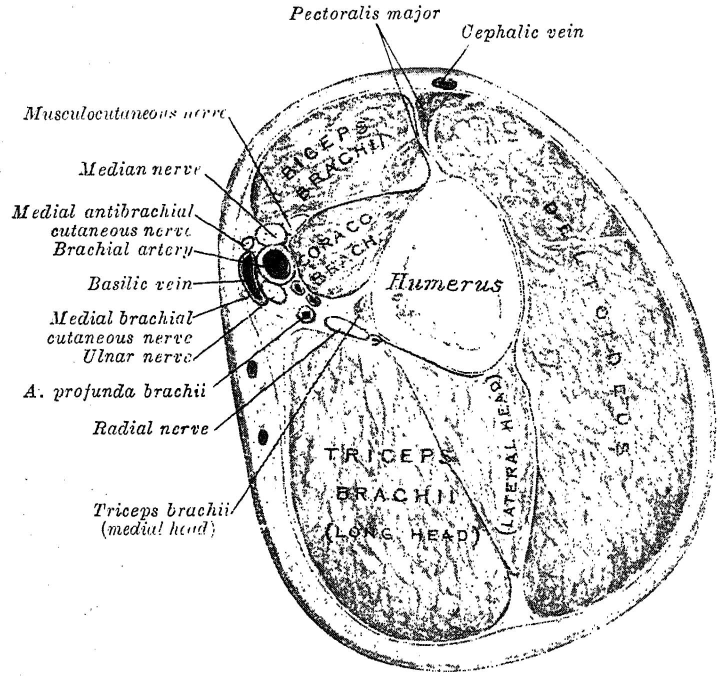
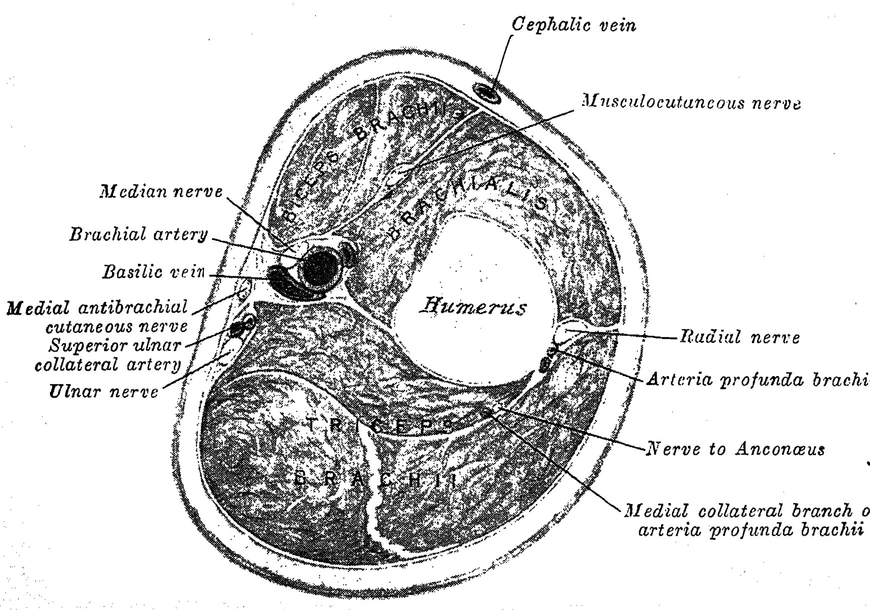


FIG. 683.—A transverse section through the arm, a little below the middle of the body of the humerus.

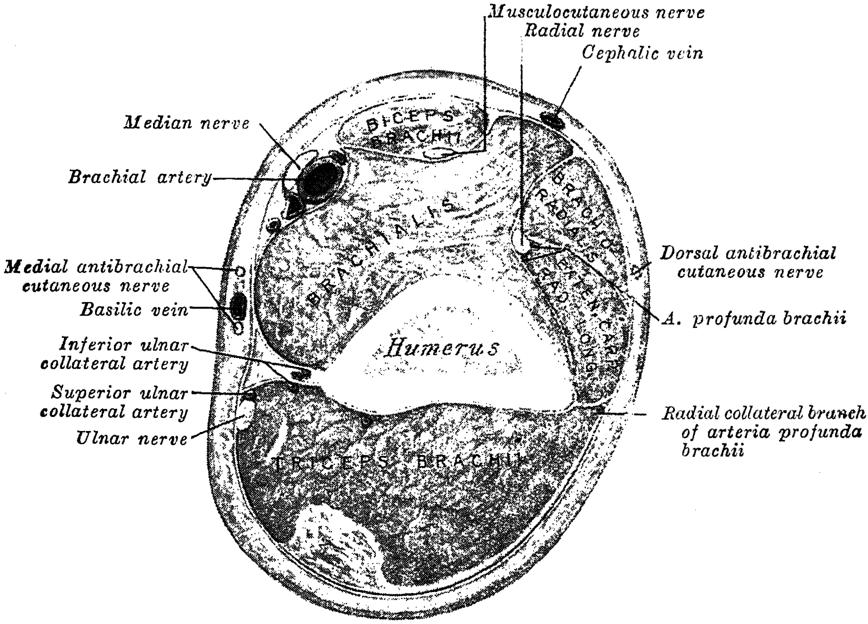


the aneurysm needle should be passed round the artery from the medial side so as to avoid injuring the basilic vein.

In the case of a high division, the two arteries are usually placed side by side; and if they are exposed in an operation, the surgeon should endeavour to ascertain, by alternately pressing on each vessel, which is connected with the wound or aneurysm, when a ligature may be applied accordingly; if pulsation or hæmorrhage ceases only when both vessels are compressed, both must be tied.

In the middle of the arm the brachial artery may be exposed by making an incision along the medial margin of the Biceps brachii (fig. 679, B). The forearm is then bent so as to relax this muscle which should be drawn aside, and the fascia carefully divided, when the median nerve will be exposed lying upon (sometimes behind) the artery; the nerve being drawn medialwards and the muscle lateralwards, the artery should be separated from its accompanying veins and secured. In this situation the superior ulnar collateral artery (inferior profunda artery) may be mistaken for the main trunk, especially if enlarged

FIG. 684.—A transverse section through the arm, 2 cm. proximal to the medial epicondyle of the humerus.



from the collateral circulation having become established; this may be avoided by directing the incision towards the Biceps brachii, rather than towards the Triceps brachii.

The lower part of the brachial artery (fig. 679, C) is of interest on account of the relation it bears to the veins most commonly opened in venesection. Of these vessels, the median cubital vein (median basilic vein) is the largest and most prominent, and consequently the one usually selected for the operation. This vein runs parallel with the brachial artery, from which it is separated by the lacertus fibrosus (bicipital fascia), and care should be taken, in opening the vein, not to carry the incision so deep as to endanger the artery.

Collateral Circulation.—After the application of a ligature to the brachial artery in the upper third of the arm, the circulation is carried on by branches from the humeral circumflex and subscapular arteries anastomosing with ascending branches from the arteria profunda brachii. If the artery be tied below the origins of the arteria profunda brachii and superior ulnar collateral artery, the circulation is maintained through the anastomoses around the elbow-joint (p. 652).

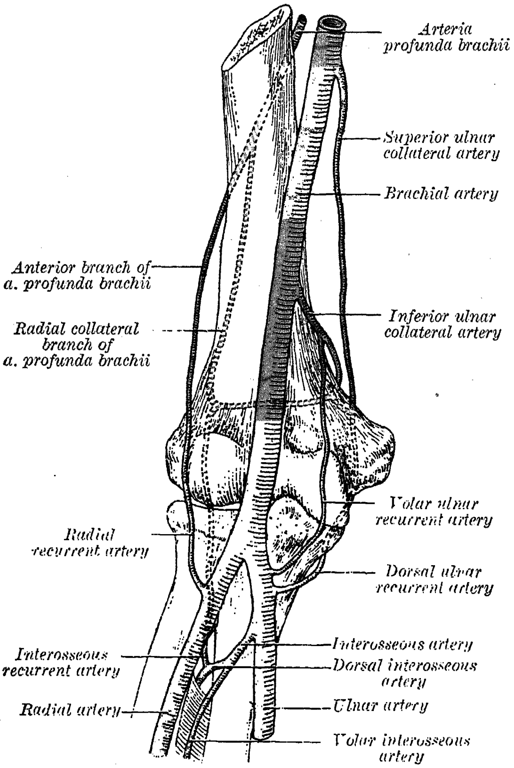
The branches of the brachial artery are:

1. Arteria profunda brachii.
2. Nutrient.
3. Superior ulnar collateral.
4. Inferior ulnar collateral.
5. Muscular.

1. The **arteria profunda brachii** (superior profunda artery) (figs. 681, 683) is a large vessel which arises from the medial and posterior part of the brachial artery,

just distal to the lower border of the Teres major. It follows closely the radial nerve, running at first backwards between the long and medial heads of the Triceps brachii, then along the sulcus for the radial nerve, where it is covered by the lateral head of the Triceps brachii. Reaching the lateral side of the arm, it pierces the lateral intermuscular septum, and, descending between the Brachioradialis and the Brachialis to the front of the lateral epicondyle of the humerus, ends by anastomosing with the radial recurrent artery. It gives branches to the Deltoideus and to the muscles between which it lies; it supplies an occasional *nutrient artery* which enters the humerus behind the deltoid tuberosity. A branch ascends between the long and lateral heads of the Triceps brachii to anastomose with the posterior humeral circumflex artery; a *middle collateral branch* descends in the medial head of the Triceps brachii with the nerve which supplies the Anconæus, and assists in forming the anastomosis above the olecranon; a *radial collateral branch* (posterior branch of superior profunda) runs down behind the lateral intermuscular septum to the back of the lateral epicondyle of the humerus, where it anastomoses with the interosseous recurrent and the inferior ulnar collateral arteries.

FIG. 685.—A diagram of the arterial anastomosis around the elbow-joint.



2. The **nutrient artery** of the humerus arises about the middle of the arm; it enters the nutrient canal near the insertion of the Coracobrachialis, and is directed downwards.

3. The **superior ulnar collateral artery** (inferior profunda artery) (figs. 681, 683), of small size, arises from the brachial a little below the middle of the arm; it frequently springs from the upper part of the arteria profunda brachii. It accompanies the ulnar nerve, pierces the medial intermuscular septum, descends between the medial epicondyle and the olecranon, and ends under the Flexor carpi ulnaris by anastomosing with the dorsal ulnar recurrent and inferior ulnar collateral arteries. It sometimes sends a branch in front of the medial epicondyle, to anastomose with the volar ulnar recurrent artery.

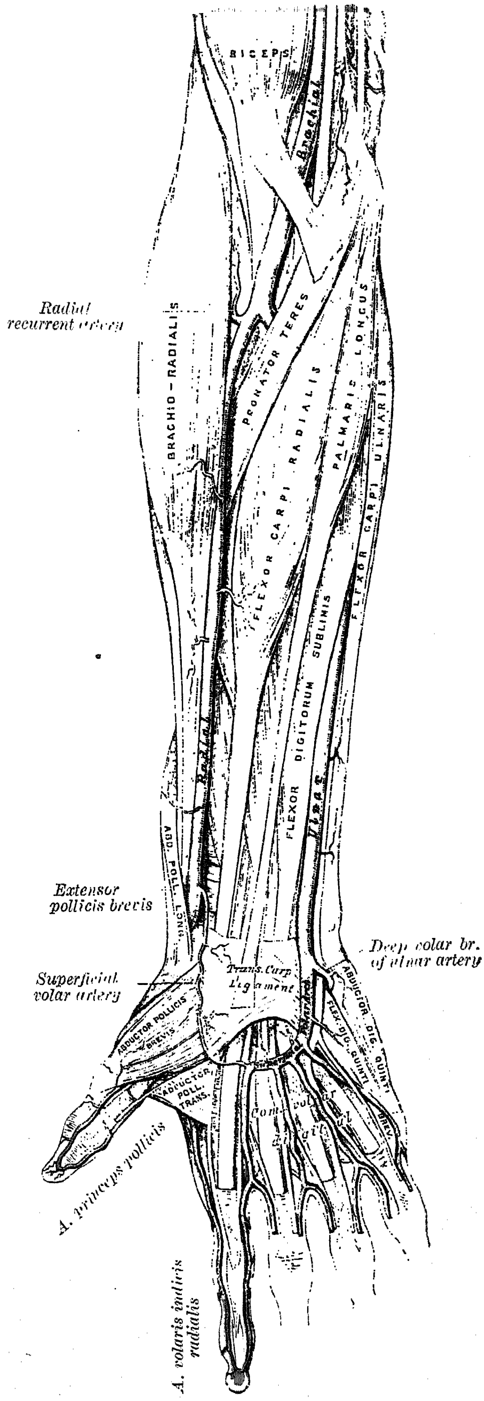
4. The **inferior ulnar collateral artery** (arteria anastomotica magna) (figs. 681, 684) arises about 5 cm. above the elbow. It passes medialwards upon the Brachialis and, piercing the medial intermuscular septum, winds round the back of the humerus between the Triceps brachii and the bone, forming, by its junction with the arteria profunda brachii, an arch above the olecranon fossa. As the vessel lies on the Brachialis, it gives off branches which ascend to join the superior ulnar collateral artery; others descend in front of the medial epicondyle, to anastomose with the volar ulnar recurrent artery. Behind the medial epicondyle a branch anastomoses with the superior ulnar collateral and dorsal ulnar recurrent arteries.

5. The **muscular branches,** three or four in number, are distributed to the Coracobrachialis, Biceps brachii, and Brachialis.

The **anastomosis around the elbow-joint** (fig. 685.)—The vessels engaged in this anastomosis may be conveniently divided into those situated *in front* of, and those *behind* the medial and lateral epicondyles of the humerus. The branches anastomosing *in front* of the medial epicondyle are: the anterior branches of the

superior and inferior ulnar collateral arteries and the volar ulnar recurrent artery. Those *behind* the medial epicondyle are: the superior and inferior ulnar collateral arteries and the dorsal ulnar recurrent artery. The branches anastomosing *in front* of the lateral epicondyle are: the terminal part of the arteria profunda brachii and the radial recurrent artery. Those *behind* the lateral epicondyle are: the radial collateral branch (posterior branch) of the arteria profunda brachii, the inferior ulnar collateral, and interosseous recurrent arteries. There is also an arch of anastomosis above the olecranon, formed by the inferior ulnar collateral artery joining with the middle and radial collateral branches of the arteria profunda brachii, and with the interosseous recurrent and the dorsal ulnar recurrent arteries (fig. 685).

Fig. 686.—The right radial and ulnar arteries. Superficial dissection.



The Radial Artery (figs. 686, 687, 689)

The **radial artery**, though smaller than the ulnar artery, appears, from its course, to be the more direct continuation of the brachial trunk. It begins at the division of the brachial, about 1 cm. below the bend of the elbow, and passes along the radial side of the forearm to the wrist. It then winds backwards, round the lateral side of the carpus, under cover of the tendons of the Abductor pollicis longus and Extensores pollicis brevis et longus to the proximal end of the space between the first and second metacarpal bones where it passes forwards between the two heads of the first Interosseus dorsalis, into the palm of the hand; it crosses towards the ulnar side of the palm, and unites with the deep volar branch of the ulnar artery to form the deep volar arch. The radial artery is therefore divisible into three portions, one in the forearm, a second at the wrist, and a third in the hand.

Relations.—(*a*) *In the forearm* (figs. 686, 687 692), the radial artery extends from the neck of the radius to the front part of its styloid process, being placed to the medial side of the body of the bone above, and in front of it below. Its upper part is overlapped by the fleshy belly of the Brachioradialis; the rest of the artery is only covered with the skin, and the superficial and deep fasciæ. It lies

the posterior belly of the Digastricus to the interval between the transverse process of the atlas vertebra and the mastoid process of the temporal bone, and passes horizontally backwards, grooving the surface of the latter bone, being covered by the Sternocleidomastoideus, Splenius capitis, Longissimus capitis, and Digastricus, and resting upon the Rectus capitis lateralis, Obliquus superior, and Semispinalis capitis. It then runs vertically upwards, pierces the fascia connecting the cranial attachment of the Trapezius with the Sternocleidomastoideus, and ascends in a tortuous course in the superficial fascia of the scalp, where it divides into numerous branches. Its terminal portion is accompanied by the greater occipital nerve.

The branches of the occipital artery are :

Sternocleidomastoid.	Auricular.	Meningeal.
Mastoid.	Muscular.	Occipital.
	Ramus descendens.	

The **sternocleidomastoid branch** generally arises from the beginning of the occipital artery, but sometimes springs directly from the external carotid artery. It passes downwards and backwards over the hypoglossal nerve, and enters the substance of the Sternocleidomastoideus, in company with the accessory nerve ; it anastomoses with the sternocleidomastoid branch of the superior thyreoid artery.

The **mastoid branch**, small in size and sometimes absent, enters the cranial cavity through the mastoid foramen ; it gives branches to the mastoid air-sinuses and the dura mater, and anastomoses with the middle meningeal artery.

The **auricular branch** supplies the back of the concha and anastomoses with the posterior auricular artery.

Muscular branches are supplied to the Digastricus, Stylohyoideus, Splenius, and Longissimus capitis.

The **ramus descendens** (arteria princeps cervicis) (fig. 668) arises from the occipital artery as the latter lies on the Obliquus superior, and divides into a superficial and a deep branch. The superficial branch passes beneath the Splenius, and anastomoses with the ascending branch of the transverse cervical artery ; the deep branch descends between the Semispinales capitis et colli, and anastomoses with the vertebral artery, and with the arteria profunda cervicalis, a branch of the costocervical trunk. The anastomosis between these vessels assists in establishing the collateral circulation after ligature of the common carotid or subclavian artery.

The **meningeal branches** ascend with the internal jugular vein, and enter the skull through the jugular foramen and condyloid canal, to supply the dura mater in the posterior fossa.

The **occipital branches**, the terminal branches, are distributed to the scalp, and reach as high as the vertex of the skull ; they are very tortuous, and lie between the skin and the Occipitalis, anastomosing with the artery of the opposite side and with the posterior auricular and temporal arteries, and supplying the Occipitalis, the skin, and the pericranium. One of the terminal branches may give off a meningeal twig which passes through the parietal foramen.

6. The **posterior auricular artery** (fig. 664) is small and arises from the external carotid artery immediately above the Digastricus and Stylohyoideus. It ascends, under cover of the parotid gland, on the styloid process of the temporal bone, to the groove between the cartilage of the auricula and the mastoid process, where it divides into auricular and occipital branches.

In addition to supplying small branches to the Digastricus, Stylohyoideus, Sternocleidomastoideus, and parotid gland, this vessel gives off the three following branches :

Stylomastoid.	Auricular.	Occipital.

The **stylomastoid artery** enters the stylomastoid foramen and supplies the tympanic cavity, the tympanic antrum, the mastoid air-sinuses, and the semicircular canals. In the young subject a branch from this vessel forms, with the anterior tympanic artery from the internal maxillary, a vascular circle which surrounds and supplies small vessels to the deep surface of the tympanic membrane. It anastomoses with the superficial petrosal branch of the middle meningeal artery by a twig which enters the hiatus canalis facialis.

The **auricular branch** ascends beneath the Auricularis posterior, and ramifies on the back of the auricula ; some of its branches pierce the auricula, and others curve round its margin to supply its lateral surface. It anastomoses with the parietal and anterior auricular branches of the superficial temporal artery.

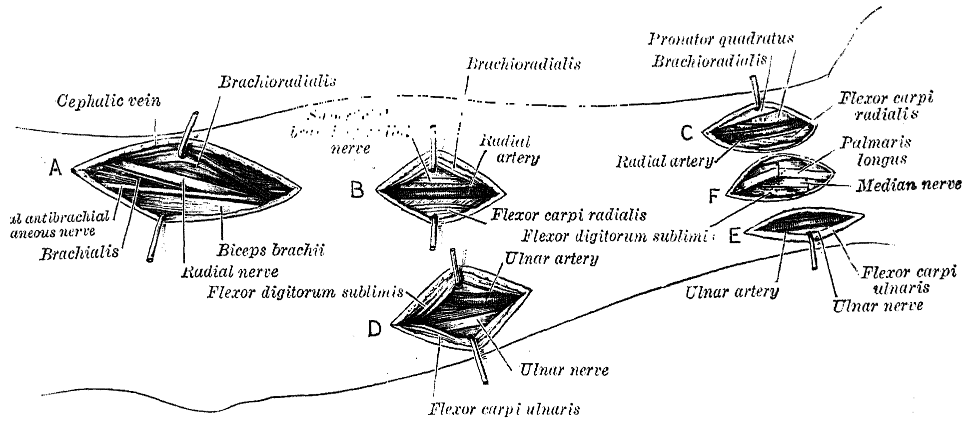
Ligature of the radial artery is required in cases of wounds either of its trunk, or of some of its branches, or for aneurysm.

To tie the artery in the proximal one-third of the forearm (fig. 688, B), an incision 7 or 8 cm. long should be made through the skin, in a line drawn from the centre of the bend of the elbow to the front of the styloid process of the radius, avoiding the branches of the medial antibrachial vein; when the fascia of the arm is divided, and the Brachioradialis drawn aside, the artery will be exposed. The venæ comitantes should be separated from the vessel and the ligature passed from the radial to the ulnar side.

In the middle one-third of the forearm the artery may be exposed by making an incision of similar length on the medial border of the Brachioradialis. In this situation, the superficial part of the radial nerve lies in close relation with the lateral side of the artery, and should be avoided.

In the distal one-third of the forearm (fig. 688, C) the artery is easily secured by dividing the skin and fascia between the tendons of the Brachioradialis and Flexor carpi radialis. When operating on the cadaver, students are apt to forget how near to the surface the artery is in this situation.

FIG. 688.—Dissections to show the radial and median nerves, and the radial and ulnar arteries.



The branches of the radial artery may be divided into three groups, corresponding with the three regions in which the vessel is situated.

In the forearm.	*At the wrist.*	*In the hand.*
Radial recurrent.	Dorsal carpal.	Princeps pollicis.
Muscular.	First dorsal metacarpal.	Volaris indicis radialis.
Volar carpal.		
Superficial volar.		

The **radial recurrent artery** arises immediately below the elbow. It passes between the branches of the radial nerve, and ascends beneath the Brachioradialis, lying on the Supinator and Brachialis; it supplies these muscles and the elbow-joint, and anastomoses with the anterior terminal part of the arteria profunda brachii.

The **muscular branches** are distributed to the muscles on the radial side of the forearm.

The **volar carpal branch** is a small vessel which arises near the lower border of the Pronator quadratus, and, running across the volar surface of the carpus, anastomoses under cover of the flexor tendons, with the volar carpal branch of the ulnar artery. This anastomosis is joined by a branch from the volar interosseous artery, and by recurrent branches from the deep volar arch, thus forming a *volar carpal network* which supplies the articulations of the wrist and carpus.

The **superficial volar branch** (fig. 686) arises from the radial artery, where this vessel is about to wind round the lateral side of the wrist. Running forwards, it passes through, occasionally over, the muscles of the ball of the thumb, which it supplies, and sometimes anastomoses with the terminal portion of the ulnar artery completing the superficial volar arch. This vessel varies considerably in size: usually it is very small, and ends in the muscles of the thumb; sometimes it is as large as the continuation of the radial artery.

The **dorsal carpal branch** (fig. 693) is a small vessel which arises beneath the extensor tendons of the thumb, and, running across the dorsal surface of the carpus under cover of the extensor tendons, anastomoses with the dorsal carpal branch of the ulnar artery, and with the volar and dorsal interosseous arteries, to form a *dorsal carpal network.* Arising from this network are three slender *dorsal metacarpal arteries,* which descend on the second, third, and fourth Interossei dorsales and bifurcate into dorsal digital branches for the supply of the adjacent sides of the index, middle, ring, and little fingers; they anastomose with the proper volar digital branches of the superficial volar arch; near their origins they anastomose with the deep volar arch by the *superior perforating arteries,* and near their points of bifurcation with the common volar digital vessels of the superficial volar arch by the *inferior perforating arteries.*

The **first dorsal metacarpal artery** (fig. 693) arises just before the radial artery passes between the two heads of the first Interosseus dorsalis, and divides almost immediately into two branches which supply the adjacent sides of the thumb and index finger; the radial side of the thumb receives a branch directly from the radial artery.

The **arteria princeps pollicis** (fig. 689) arises from the radial artery as the latter turns medialwards to the deep part of the hand; it descends between the first Interosseus dorsalis and the oblique part of the Adductor pollicis, along the medial side of the metacarpal bone of the thumb to the base of the first phalanx, where it lies beneath the tendon of the Flexor pollicis longus and divides into two branches. These make their appearance between the medial and lateral insertions of the oblique part of the Adductor pollicis, and run along the sides of the thumb, forming on the volar surface of the last phalanx an arch, from which branches are distributed to the integument and subcutaneous tissue of the thumb.

The **arteria volaris indicis radialis** (fig. 689), frequently a branch of the proximal part of the arteria princeps pollicis, descends between the first Interosseus dorsalis and the transverse part of the Adductor pollicis, and runs along the lateral side of the index finger to its extremity: it anastomoses with the proper digital artery supplying the medial side of the finger. At the lower border of the transverse part of the Adductor pollicis this vessel anastomoses with the arteria princeps pollicis, and gives a communicating branch to the superficial volar arch.

The arteria princeps pollicis and arteria volaris indicis radialis may spring from a common trunk which is named the *first volar metacarpal artery.*

The **deep volar arch** (deep palmar arch) (fig. 689) is formed by the anastomosis of the terminal part of the radial artery with the deep volar branch of the ulnar artery. It lies upon the proximal ends of the metacarpal bones and on the Interossei, and is covered by the oblique part of the Adductor pollicis, the flexor tendons of the fingers, and the Lumbricales. Alongside of it, but running towards the lateral side of the hand, is the deep branch of the ulnar nerve.

The branches of the deep volar arch are: volar metacarpal, perforating, and recurrent.

The **volar metacarpal arteries** (fig. 689), three in number, arise from the convexity of the deep volar arch; they run distally upon the Interossei of the second, third, and fourth spaces, and join, at the clefts of the fingers, the common digital branches of the superficial volar arch.

The **perforating branches,** three in number, pass backwards from the deep volar arch, through the second, third, and fourth interosseous spaces and between the heads of the corresponding Interossei dorsales, to anastomose with the dorsal metacarpal arteries.

The **recurrent branches** arise from the concavity of the deep volar arch; they ascend in front of the wrist, supply the intercarpal articulations, and end in the volar carpal network.

The Ulnar Artery (figs. 686, 689, 692)

The **ulnar artery,** the larger of the two terminal branches of the brachial artery, begins about 1 cm. below the bend of the elbow, and, passing obliquely downwards, reaches the medial side of the forearm at a point about midway between the elbow and the wrist. It then runs along the medial side to the wrist, crosses the transverse carpal ligament on the lateral side of the pisiform

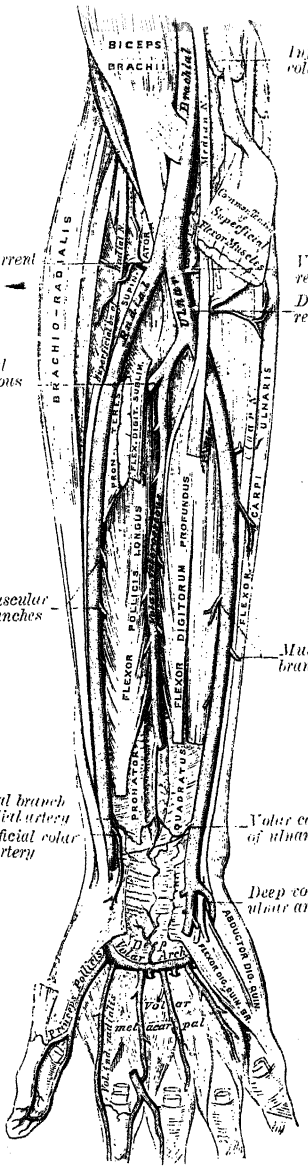
bone and immediately beyond this bone divides into two branches, which enter into the formation of the superficial and deep volar arches.

Relations.—(*a*) *In the forearm.*—The *proximal half* of the vessel (figs. 686, 687) is deeply seated, passing obliquely under cover of the Pronator teres, Flexor carpi radialis, Palmaris longus, and Flexor digitorum sublimis to the medial side of the forearm, where it is overlapped by the Flexor carpi ulnaris; it lies upon the Brachialis and the Flexor digitorum profundus. The median nerve is on the medial side of the artery for about 2·5 cm. and then crosses the vessel, but is separated from it by the ulnar head of the Pronator teres. The *distal half* (figs. 686, 692) lies upon the Flexor digitorum profundus; it is covered by the skin, superficial and deep fasciæ, and is placed between the Flexor carpi ulnaris and Flexor digitorum sublimis.

It is accompanied by two venæ comitantes, and is overlapped in its middle one-third by the Flexor carpi ulnaris; the ulnar nerve lies on the medial side of the lower two-thirds of the artery, and the palmar cutaneous branch of this nerve descends on the distal part of the vessel to the palm of the hand.

(*b*) *At the wrist* (figs. 689, 690, 691) the ulnar artery is covered by the skin and the volar carpal ligament, and lies upon the transverse carpal ligament. On its medial side are the pisiform bone and the ulnar nerve.

Fig. 689.—The right radial and ulnar arteries. Deep dissection.



Peculiarities.—The ulnar artery varies in its origin in about 8 per cent. of cases; it frequently arises above the elbow, the brachial being more often the source of origin than the axillary. When its origin is normal, the course of the vessel is rarely changed. When the artery arises high up, it is usually superficial to the flexor muscles in the forearm, lying commonly beneath the fascia more rarely between the fascia and skin; the brachial artery then gives off the common interosseous artery, and the latter, the anterior and posterior ulnar recurrent arteries. Occasionally it is subcutaneous in the upper part of the forearm, and subaponeurotic in the lower part.

When the ulnar artery is superficial there is some danger of its being wounded in opening the median cubital vein for the purpose of transfusing blood or injecting saline solution.

Applied Anatomy.—Ligature of the ulnar artery (fig. 688, D) in the upper one-half of the forearm is difficult as this part of the vessel is deeply seated beneath the superficial flexor muscles. An incision is to be made in the course of a line drawn from the front of the medial epicondyle of the humerus to the lateral side of the pisiform bone, so that

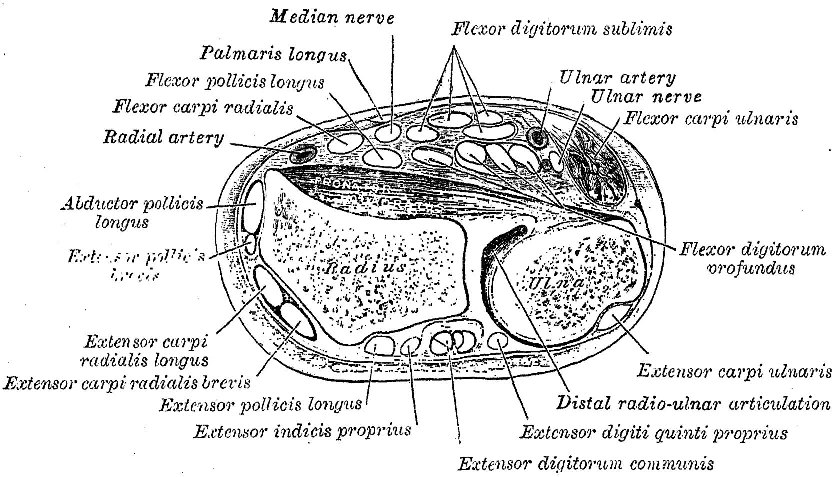
the centre of the incision is three fingers' breadths below the medial epicondyle. The skin and superficial fascia having been divided, and the deep fascia exposed, the white line which separates the Flexor carpi ulnaris from the other flexor muscles is to be sought for, and the fascia incised in this line. On separating the Flexor carpi ulnaris from the other muscles the ulnar nerve will be exposed lying on the Flexor digitorum profundus, and must be drawn aside. The artery, accompanied by its venæ comitantes, lies lateral to the nerve. In the middle and lower parts (fig. 688, E) of the forearm, the artery may be secured easily by making an incision on the radial side of the tendon of the Flexor carpi ulnaris: when the deep fascia is divided, and the tendon separated from the Flexor digitorum sublimis, the artery and its venæ comitantes will be exposed, lying lateral to the ulnar nerve.

The branches of the ulnar artery may be arranged in the following groups:

In the forearm	Anterior recurrent. Posterior recurrent. Common interosseous. Muscular.	*At the wrist* *In the hand*	Volar carpal. Dorsal carpal. Deep volar. Superficial volar arch.

The **volar ulnar recurrent artery** (figs. 685, 689), a small branch, arises immediately below the elbow-joint, runs upwards between the Brachialis and Pronator teres, supplies twigs to those muscles, and, in front of the medial epicondyle, anastomoses with the superior and inferior ulnar collateral arteries.

FIG. 690.—A transverse section through the distal ends of the left radius and ulna. Superior aspect.



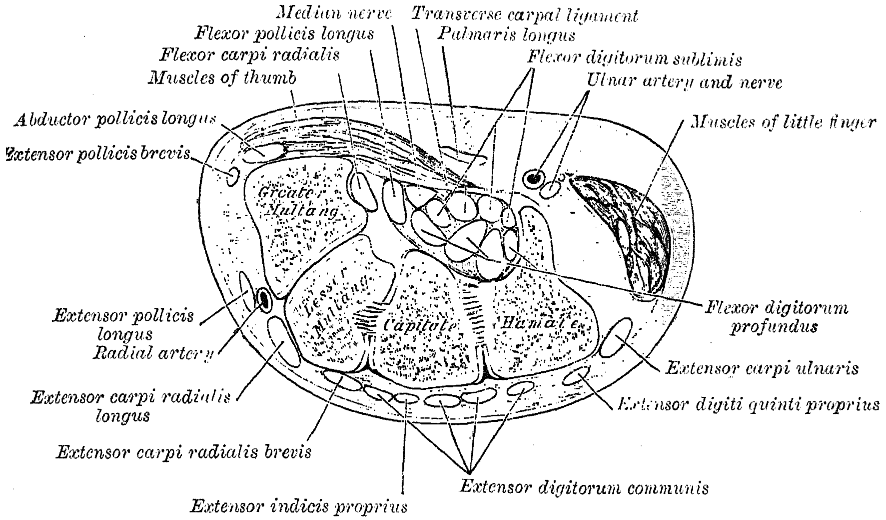
The **dorsal ulnar recurrent artery** (figs. 685, 689) is much larger, and arises somewhat lower than the volar artery. It passes backwards and medialwards on the Flexor digitorum profundus, behind the Flexor digitorum sublimis, and ascends behind the medial epicondyle of the humerus. In the interval between this process and the olecranon, it lies beneath the Flexor carpi ulnaris, and ascends between the heads of this muscle, in relation with the ulnar nerve; it supplies the neighbouring muscles and the elbow-joint, and anastomoses with the superior and inferior ulnar collateral and the interosseous recurrent arteries (fig. 693).

The **common interosseous artery** (fig. 689), about 1 cm. in length, arises immediately below the tuberosity of the radius, and, passing backwards to the upper border of the antibrachial interosseous membrane, divides into two branches, the *volar* and *dorsal interosseous arteries*.

The **volar interosseous artery** (figs. 689, 692) descends on the volar surface of the antibrachial interosseous membrane, accompanied by the volar interosseous branch of the median nerve, and overlapped by the contiguous margins of the Flexor digitorum profundus and Flexor pollicis longus; it gives off *muscular* branches, and the *nutrient* arteries of the radius and ulna. At the upper border of the Pronator quadratus it pierces the interosseous membrane and reaches the back of the forearm,

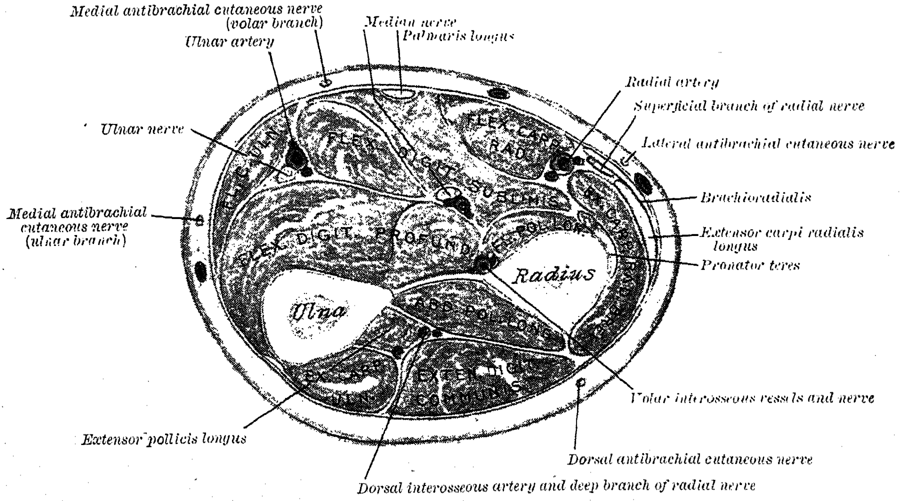
where it anastomoses with the dorsal interosseous artery and descends on the back of the wrist in the compartment of the dorsal carpal ligament containing the tendons of the Extensor digitorum communis and Extensor indicis proprius, and joins the dorsal carpal network. The volar interosseous artery gives off a slender branch,

Fig. 691.—A transverse section through the left wrist. Superior aspect.



the *arteria mediana*, which accompanies the median nerve, and sends offsets to its substance; this artery is sometimes much enlarged, and runs with the median nerve into the palm of the hand. Before the volar interosseous artery pierces the interosseous membrane, it sends a branch downwards behind the Pronator quadratus to join the volar carpal network.

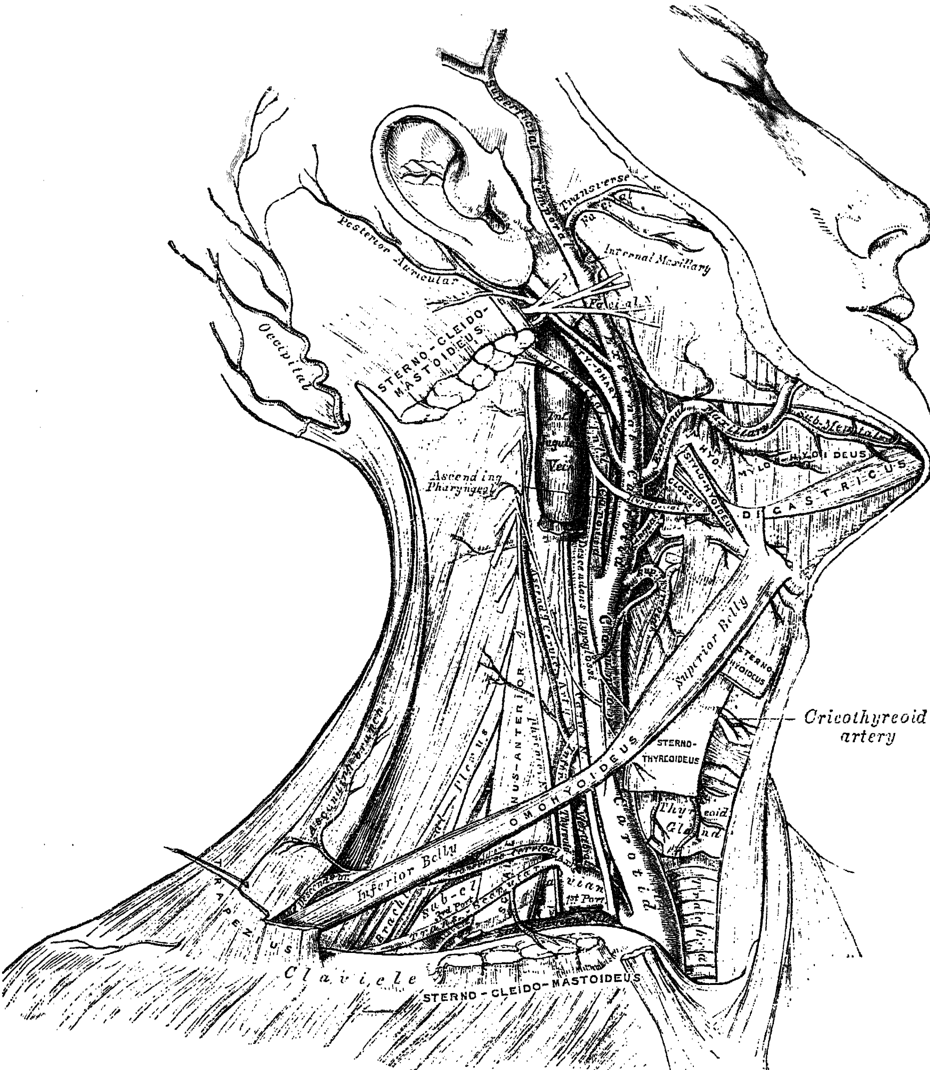
Fig. 692.—A transverse section through the middle of the forearm.



The **dorsal interosseous artery** (figs. 692, 693), usually smaller than the volar interosseous artery, passes backwards between the oblique cord and the upper border of the antibrachial interosseous membrane. It appears on the back of the forearm between the contiguous borders of the Supinator and the Abductor

Behind the veins, the nerve to the Subclavius descends in front of the artery. The terminal part of the artery lies behind the clavicle and the Subclavius, and is crossed by the transverse scapular vessels. The subclavian vein is in front of, and at a slightly lower level than, the artery. The lowest trunk of the brachial plexus

Fig. 675.—A dissection of the right side of the neck, showing the carotid and subclavian arteries.



lies *behind* the artery and intervenes between it and the Scalenus medius. *Above*, and to its *lateral side*, are the upper trunks of the brachial plexus, and the Omohyoideus. *Below*, it rests on the upper surface of the first rib.

Peculiarities.—The subclavian arteries vary in their origin, their course, and the height to which they rise in the neck.

The right subclavian may arise from the innominate above or below the level of the sternoclavicular articulation. It may arise as a separate trunk from the arch of the aorta, and may then be either its first, second, third, or last branch; in the majority of cases it is the first or last. When it is the first branch, it occupies the ordinary position of the innominate artery; when the second or third, it passes behind the right carotid artery; and when the last it arises from the left extremity of the arch, and ascends obliquely towards

arteria princeps pollicis. The arch passes across the palm, describing a curve, with its convexity downwards.

Relations.—It is covered by the skin, the Palmaris brevis, and the palmar aponeurosis. It lies upon the transverse carpal ligament, the Flexor digiti quinti brevis, the flexor tendons, the Lumbricales, and the branches of the median nerve.

Three **common volar digital arteries** (fig. 686) arise from the convexity of the superficial volar arch and proceed downwards on the second, third, and fourth Lumbricales. Each is joined by the corresponding volar metacarpal artery, and then divides into a pair of *proper volar digital arteries* which run along the contiguous sides of the index, middle, ring, and little fingers, behind the corresponding digital nerves; they anastomose freely in the subcutaneous tissue of the finger tips and by smaller branches near the interphalangeal joints. Each gives off two dorsal branches which anastomose with the dorsal digital arteries, and supply the soft parts on the back of the second and third phalanges, including the matrix of the finger-nail. The proper volar digital artery for the medial side of the little finger springs from the ulnar artery under cover of the Palmaris brevis.

Applied Anatomy.—Wounds of the volar arches are always difficult to deal with. When the superficial arch is involved it is generally possible (enlarging the wound when necessary) to secure the vessel and tie it on both sides of the bleeding point; or in cases where it is found impossible to encircle the vessel with a ligature, a pair of artery clips may be applied and left on for twenty-four or forty-eight hours. Failing this, the wound may be plugged with gauze and an outside dressing carefully bandaged on. The plug should remain untouched for three or four days. It is useless in these cases to ligature one of the arteries of the forearm alone, and simultaneous ligature of both radial and ulnar arteries above the wrist is often unsuccessful, on account of the anastomosis carried on by the carpal networks. Therefore, upon the failure of pressure to arrest hæmorrhage, it is expedient to apply a ligature to the brachial artery.

When an incision for deep-seated suppuration in the tendon-sheath is required, the situation of the superficial arch must always be borne in mind, and the incisions placed either above or below it. The position of the common digital branches of the artery must also be remembered, and the incisions made in front of the heads of the metacarpal bones and not between them.

THE ARTERIES OF THE TRUNK

The Descending Aorta

The **descending aorta** is divided into two portions, the *thoracic* and *abdominal*, in correspondence with the two great cavities in which it is situated.

The Thoracic Aorta (fig. 694)

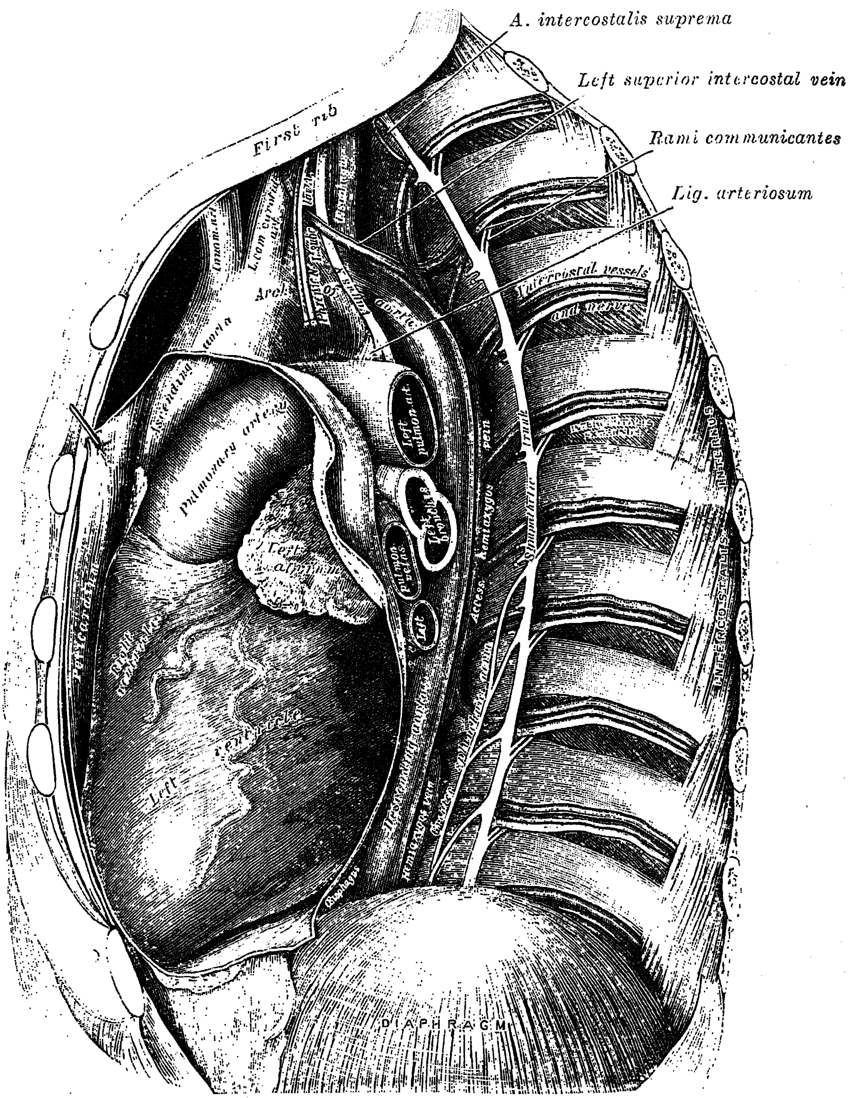
The **thoracic aorta** is contained in the posterior mediastinal cavity. It begins at the lower border of the fourth thoracic vertebra where it is continuous with the aortic arch (p. 600), and ends in front of the lower border of the twelfth thoracic vertebra at the aortic hiatus in the Diaphragm. At its origin, it is situated on the left of the vertebral column; as it descends it approaches the median line, and at its termination lies in front of the column.

Relations.—It is in relation, *anteriorly*, from above downwards, with the root of the left lung, the pericardium, which separates it from the left atrium, the œsophagus, and the Diaphragm; *posteriorly*, with the vertebral column, the hemiazygos and accessory hemiazygos veins; on the *right side*, with the azygos vein and thoracic duct; on the *left side*, with the left pleura and lung. The œsophagus, with its accompanying plexus of nerves, lies on the right side of the aorta above; but at the lower part of the thorax it is placed in front of the aorta, and, close to the Diaphragm, is situated on its left side.

Peculiarities.—The lumen of the aorta is occasionally found to be partly or completely obliterated, either at the aortic isthmus, or close to the point where the ductus arteriosus opens into it. This condition is known as *coarctation of the aorta.* It may be either congenital or acquired. In the former case the infant usually dies at or soon after birth. When acquired it is apparently due to an abnormal extension of the peculiar tissue of

the ductus into the aortic wall, giving rise to a simultaneous stenosis of both vessels as it contracts after birth. This form of coarctation is compatible with many years of normal life, and leads to the establishment of an extensive collateral circulation to carry blood to the aorta immediately below the stenosis by means of the following vessels—Firstly, the internal mammary, anastomosing with the intercostal arteries, with the inferior phrenic of the abdominal aorta by means of the musculophrenic and pericardiacophrenic, and largely with the inferior epigastric. Secondly, the costocervical trunk, anastomosing

Fig. 694.—The heart and the thoracic aorta. Left lateral aspect.



anteriorly by means of a large branch with the first aortic intercostal, and posteriorly with the posterior branch of the same artery. Thirdly, the inferior thyreoid, by means of a branch about the size of an ordinary radial, forming a communication with the first aortic intercostal. Fourthly, the transverse cervical, by means of very large communications with the posterior branches of the intercostals. Fifthly, the branches (of the subclavian and axillary) going to the side of the chest enlarge, and anastomose freely with the lateral branches of the intercostals. In a second case Wood describes the anastomoses in a somewhat similar manner, adding the remark, that 'the blood which was brought into the aorta through the anastomoses of the intercostal arteries appeared to be expended principally in supplying the abdomen and pelvis; while the supply to the lower extremities had passed through the internal mammary and epigastrics.'

Applied Anatomy.—Aneurysm of the thoracic aorta most commonly extends backwards along the left side of the vertebral column and leads to absorption of the bodies of the vertebræ (but not of the intervertebral fibrocartilages) and of the ribs; pressure on the intercostal nerves may give rise to radiating pains in the left upper intercostal spaces; after erosion of the vertebræ the aneurysm may compress the spinal nerve-roots or ultimately the medulla spinalis producing pains in the chest, back or loins, or paralysis below the site of the lesion; at the same time the aneurysm may project backwards under the skin as a pulsating swelling. If the aneurysm extend forward, it may press upon and displace the heart, giving rise to palpitation and other symptoms of disease of that organ; it may displace or compress the œsophagus, causing pain and difficulty of swallowing, and ultimately even open into it by ulceration, producing fatal hæmorrhage. If the aneurysm extend to the right side, it may press upon the thoracic duct; it may burst into the pleural cavity, or into the lung; or it may open into the posterior mediastinal cavity. Pressure on one of the bronchi, usually the left, will cause cough, and in time set up bronchiectasis; pressure on the left pulmonary plexus has been said to give rise to asthmatic attacks. Of late years, the diagnosis of thoracic aneurysm has been much facilitated by the employment of the x-rays, by means of which the outline of the sac may be demonstrated.

The Branches of the Thoracic Aorta

Visceral	Pericardial. Bronchial. Œsophageal.	*Parietal*	Mediastinal. Superior phrenic. Intercostal. Subcostal.

The **pericardial branches** consist of a few small vessels which are distributed to the posterior surface of the pericardium.

The **bronchial arteries** vary in number, size, and origin. There is as a rule one **right bronchial artery,** which arises from the first aortic intercostal artery, or from the upper left bronchial artery. It runs on the posterior surface of the right bronchus, dividing and subdividing along the bronchial tubes, supplying them, the areolar tissue of the lung, and the bronchial lymph-glands; it also sends branches to the pericardium and the œsophagus. The **left bronchial arteries,** usually two in number, arise from the thoracic aorta, the upper opposite the fifth thoracic vertebra, and the lower just below the left bronchus. They run on the posterior surface of the left bronchus and have a distribution similar to that of the right bronchial artery.

The **œsophageal arteries,** four or five in number, arise from the front of the aorta, and pass obliquely downwards to the œsophagus; on this they form a vascular chain which anastomoses above with the œsophageal branches of the inferior thyreoid arteries, and below with ascending branches from the left inferior phrenic and left gastric arteries.

The **mediastinal branches** are numerous small vessels which supply the lymph-glands and loose areolar tissue in the posterior mediastinal cavity.

The **superior phrenic branches** are small, and arise from the lower part of the thoracic aorta; they are distributed to the posterior part of the upper surface of the Diaphragm, and anastomose with the musculophrenic and pericardiacophrenic arteries.

The **intercostal arteries.**—There are usually nine pairs of aortic intercostal arteries. They arise from the back of the aorta, and are distributed to the lower nine intercostal spaces, the first and second spaces being supplied by the arteria intercostalis suprema, a branch of the costocervical trunk of the subclavian artery (p. 642). The *right* aortic intercostal arteries are longer than the left, on account of the position of the aorta on the left side of the vertebral column; they cross the bodies of the vertebræ behind the œsophagus, thoracic duct, and vena azygos, and are covered by the right lung and pleura. The *left* aortic intercostal arteries run backwards on the sides of the vertebræ and are covered by the left lung and pleura; the upper two vessels are crossed by the left superior intercostal vein, the lower vessels by the hemiazygos and accessory hemiazygos veins. The further course of the intercostal arteries is practically the same on both sides. Opposite the heads of the ribs the sympathetic trunk passes downwards in front of them, and the splanchnic nerves also descend in front of the lower arteries. Each artery then divides into an anterior and a posterior ramus.

Each *anterior ramus* (fig. 694) crosses its intercostal space obliquely towards the angle of the upper rib, and thence is continued forward in the costal groove. It

is placed at first between the pleura and the posterior intercostal membrane, as far as the angle of the rib; from this onward it runs between the Intercostales externus et internus, and anastomoses in front with the intercostal branch of the internal mammary or musculophrenic artery. Each artery is accompanied by a vein and a nerve, the former being above and the latter below the artery, except in the upper spaces, where the nerve is at first above the artery. The first aortic intercostal artery anastomoses with the arteria intercostalis suprema, and may form the chief supply of the second intercostal space. The lower two intercostal arteries are continued anteriorly from the intercostal spaces into the abdominal wall and anastomose with the subcostal, superior epigastric, and lumbar arteries.

Each anterior ramus gives off the following branches:

Collateral intercostal.	Lateral cutaneous.
Muscular.	Mammary.

The **collateral intercostal branch** comes off the anterior ramus of the intercostal artery near the angle of the rib, and descends to the upper border of the rib below, along which it courses to anastomose with an intercostal branch of the internal mammary or musculophrenic artery. The collateral branches of the lower two anterior rami are sometimes absent; if present, they are small and end in the abdominal muscles.

Muscular branches are given to the Intercostales and Pectorales and to the Serratus anterior; they anastomose with the highest and lateral thoracic branches of the axillary artery.

The **lateral cutaneous branches** accompany the lateral cutaneous branches of the thoracic nerves.

Mammary branches are given off by the vessels in the second, third, and fourth spaces; they increase considerably in size during the period of lactation.

The **right bronchial artery** may arise from the first intercostal artery (p. 663).

Each *posterior ramus* runs backwards through a space which is bounded above and below by the necks of the ribs, medially by the body of a vertebra, and laterally by an anterior costotransverse ligament. It gives off a *spinal branch* which enters the vertebral canal through the intervertebral foramen, and is distributed to the vertebræ and to the medulla spinalis and its membranes, anastomosing with the spinal arteries above and below and with the artery of the opposite side. The posterior ramus then courses over the transverse process with the posterior division of the thoracic nerve, supplies branches to the muscles of the back, and a cutaneous branch which accompanies the cutaneous branch of the posterior division of the nerve.

Applied Anatomy.—The position of the anterior rami of the intercostal vessels should be borne in mind in performing the operation of paracentesis thoracis. The puncture should never be made nearer the middle line posteriorly than the angle of the rib, as the artery crosses the space medial to this point. In the lateral portion of the chest, where the puncture is usually made, the artery lies at the upper part of the intercostal space, and therefore the puncture should be made just above the upper border of the rib forming the lower boundary of the space.

The relation of the Diaphragm to the deep surface of the lower intercostal spaces must be remembered, otherwise the abdominal cavity may be opened inadvertently while making incisions in these spaces.

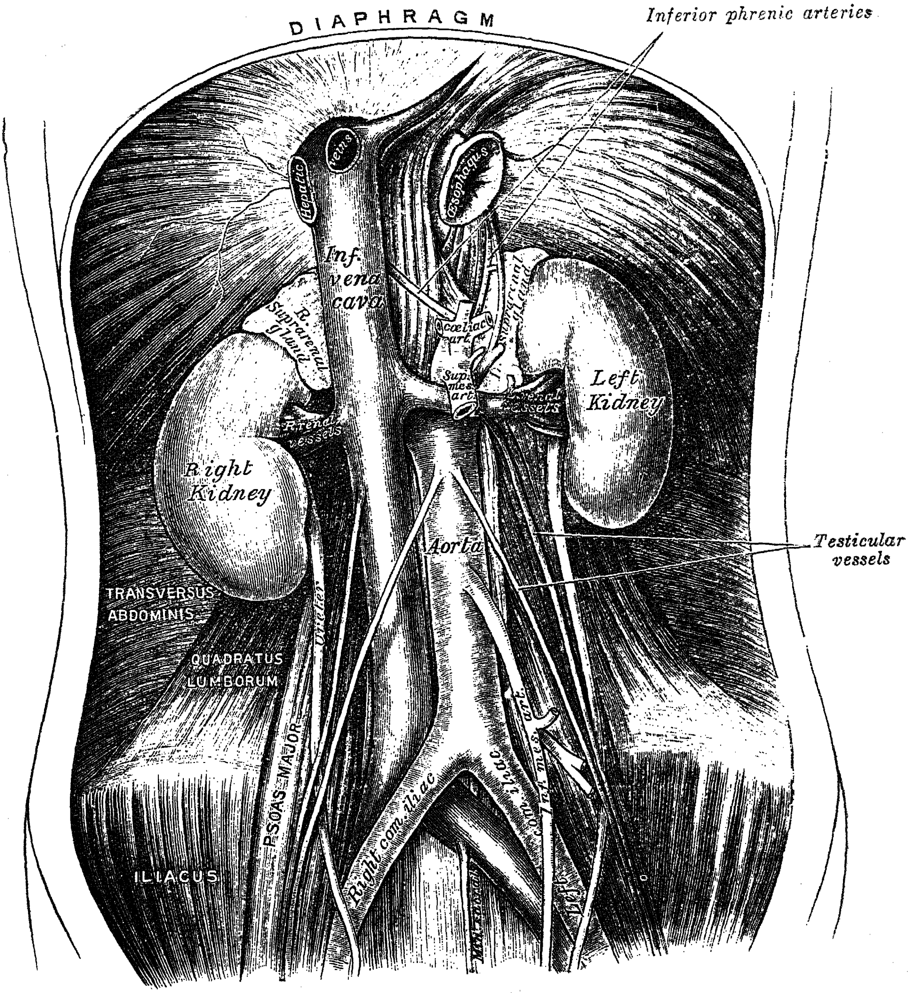
The **subcostal arteries,** so named because they lie below the last ribs, are in series with the intercostal arteries. Each passes along the lower border of the twelfth rib behind the kidney and in front of the Quadratus lumborum, and is accompanied by the twelfth thoracic nerve. It then pierces the posterior aponeurosis of the Transversus abdominis, and, passing forward between this muscle and the Obliquus internus, anastomoses with the superior epigastric, lower intercostal, and lumbar arteries. Each subcostal artery gives off a posterior branch which has a distribution similar to the posterior ramus of an intercostal artery.

A small **aberrant artery** is sometimes found arising from the right side of the thoracic aorta near the origin of the right bronchial. It passes upwards and to the right behind the trachea and the œsophagus, and may anastomose with the right arteria intercostalis suprema. It represents the remains of the right dorsal aorta (p. 121), and in a small proportion of cases is enlarged to form the first part of the right subclavian artery.

The Abdominal Aorta (fig. 695)

The **abdominal aorta** begins at the aortic hiatus of the Diaphragm, in front of the lower border of the body of the last thoracic vertebra, and, descending in front of the vertebral column, ends on the body of the fourth lumbar vertebra, a little to the left of the middle line, by dividing into the two common iliac arteries. It diminishes rapidly in size, in consequence of the large branches which arise from it.

Fig. 695.—The abdominal aorta and its branches.



Relations.—The abdominal aorta is covered, *anteriorly*, by the omental bursa and stomach, behind which are the branches of the cœliac artery and the cœliac plexus of nerves; below these, by the lienal vein, the pancreas, the left renal vein, the horizontal part of the duodenum, the root of the mesentery, the peritoneum and coils of the small intestine, and the aortic plexus of nerves. *Posteriorly*, it is separated from the lumbar vertebræ and intervertebral fibrocartilages by the anterior longitudinal ligament and the left lumbar veins. On the *right side* it is in relation above with the cisterna chyli, thoracic duct, azygos vein, and the right crus of the Diaphragm—the last separating it from the upper part of the inferior vena cava, and from the right cœliac ganglion; the inferior vena cava is in contact with the aorta below the level of the second lumbar vertebra. On the *left side* are

the left crus of the Diaphragm, the left cœliac ganglion, the ascending part of the duodenum, some coils of the small intestine, the left sympathetic trunk, inferior mesenteric and left testicular (spermatic) vessels, and the left ureter.

Applied Anatomy.—Aneurysm of the abdominal aorta occurs most frequently at its upper part close to and often involving the cœliac artery, since here the vessel rapidly narrows after giving off several large branches, and its walls have lost the support afforded higher up by the crura of the Diaphragm.

If the aneurysm enlarges forwards it forms a pulsating tumour in the left hypochondriac or epigastric regions; by pressure upwards at the same time it may interfere with the movements of the Diaphragm and embarrass respiration, or may compress the œsophagus and produce dysphagia; pressure on the stomach and cœliac plexus gives rise to dyspepsia, while jaundice may follow pressure on the bile duct and duodenum, or polyuria, albuminuria, hæmaturia and anuria pressure on the renal vessels and nerves; if the inferior vena cava is compressed there may be œdema of the lower limbs. This form of aneurysm may burst into the peritoneal cavity, behind the peritoneum, between the layers of the mesentery, or more rarely into the duodenum.

When an aneurysm of the abdominal aorta enlarges backwards it usually produces absorption of the bodies of the vertebræ, pain is invariably present and is usually of two kinds—a fixed and constant pain in the back, caused by the tumour eroding the bones, and a sharp lancinating pain radiating to the loins, hypogastrium and buttocks along the branches of the lumbar nerves which are pressed on by the tumour.

Occlusion of the abdominal aorta by thrombosis or embolism is rare, but produces very severe symptoms when it does occur. The patient complains of intense pain in the legs; pallor of the legs, followed by coldness, lividity, paresis, paralysis, and finally gangrene are likely to succeed, death usually supervening within a fortnight.

The abdominal aorta has been tied in several cases, and although none of the patients permanently recovered, still, as one case lived forty-eight days, the possibility of the re-establishment of the circulation may be considered to be proved.

Collateral Circulation.—The collateral circulation would be carried on by the anastomoses between the internal mammary and the inferior epigastric arteries; by the free communication between the superior and inferior mesenteric arteries, if the ligature were placed between these vessels; or by the anastomosis between the inferior mesenteric and the internal pudendal arteries, when (as is more common) the point of ligature is below the origin of the inferior mesenteric artery; and possibly by the anastomoses of the lumbar arteries with the branches of the hypogastric artery.

The Branches of the Abdominal Aorta (fig. 695)

The branches of the abdominal aorta may be divided into three sets: visceral, parietal, and terminal.

Visceral branches.	*Parietal branches.*
Cœliac.	Inferior phrenic.
Superior mesenteric.	Lumbar.
Inferior mesenteric.	Middle sacral.
Middle suprarenal.	
Renal.	
Testicular (in the male).	*Terminal branches.*
Ovarian (in the female).	Common iliac.

Of the visceral branches, the cœliac artery and the superior and inferior mesenteric arteries are unpaired; the suprarenal, renal, testicular, and ovarian arteries are paired. Of the parietal branches, the middle sacral artery is unpaired; the inferior phrenic and lumbar arteries are paired. The terminal branches are paired.

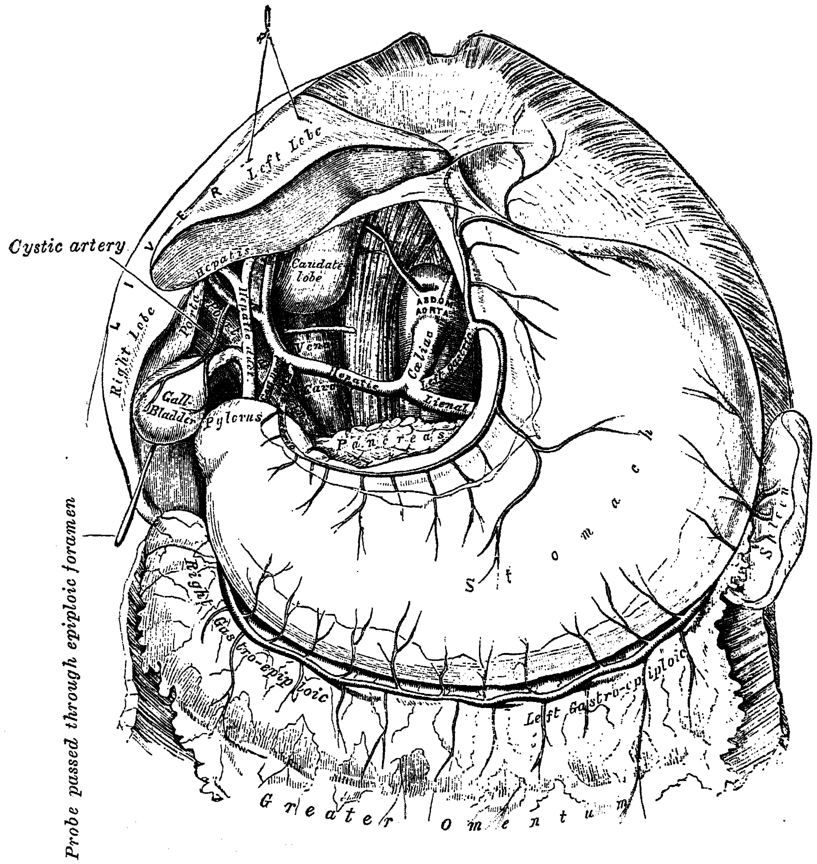
The Cœliac Artery (figs. 696, 697)

The **cœliac artery** is a thick trunk, about 1·25 cm. long, which arises from the front of the aorta, just below the aortic hiatus of the Diaphragm; it passes nearly horizontally forwards above the pancreas and the lienal vein, and divides into three large branches, (1) *left gastric*, (2) *hepatic*, and (3) *lienal* or *splenic*; it occasionally gives off one of the inferior phrenic arteries.

Relations.—The cœliac artery is covered by the omental bursa and surrounded by the cœliac plexus of nerves. On its *right side* are the right cœliac ganglion, the right crus of the Diaphragm, and the caudate process of the liver, on its *left side* the left cœliac ganglion, the left crus of the Diaphragm, and the cardiac end of the stomach. *Below* it are the upper border of the pancreas and the lienal vein.

1. **The left gastric artery** (coronary artery) (fig. 696), the smallest branch of the cœliac artery, passes upwards and to the left, behind the omental bursa, to the cardiac orifice of the stomach. Here it gives off branches which

FIG. 696.—The cœliac artery and its branches; the liver has been raised, and the lesser omentum, the anterior layer of the greater omentum, and the posterior wall of the omental bursa removed.



ascend on the œsophagus, and anastomose with the aortic œsophageal arteries; others supply the cardiac part of the stomach, and anastomose with branches of the lienal artery. The artery then turns forwards and downwards, and runs along the lesser curvature of the stomach to the pylorus, between the layers of the lesser omentum; it gives branches to both surfaces of the stomach and anastomoses with the right gastric artery.

2. The **hepatic artery** (fig. 696) is intermediate in size between the left gastric and lienal arteries. It is first directed forwards and to the right, to the upper margin of the superior part of the duodenum, forming the lower boundary of the epiploic foramen (foramen of Winslow). It then crosses in front of the portal vein, and ascends between the layers of the lesser omentum, and in front of the epiploic foramen, to the porta hepatis, where it divides into a right and a left branch, which supply the corresponding lobes of the liver, accompanying the ramifications of the portal vein and hepatic ducts. In the lesser omentum the hepatic artery lies in front of the portal vein, and on the

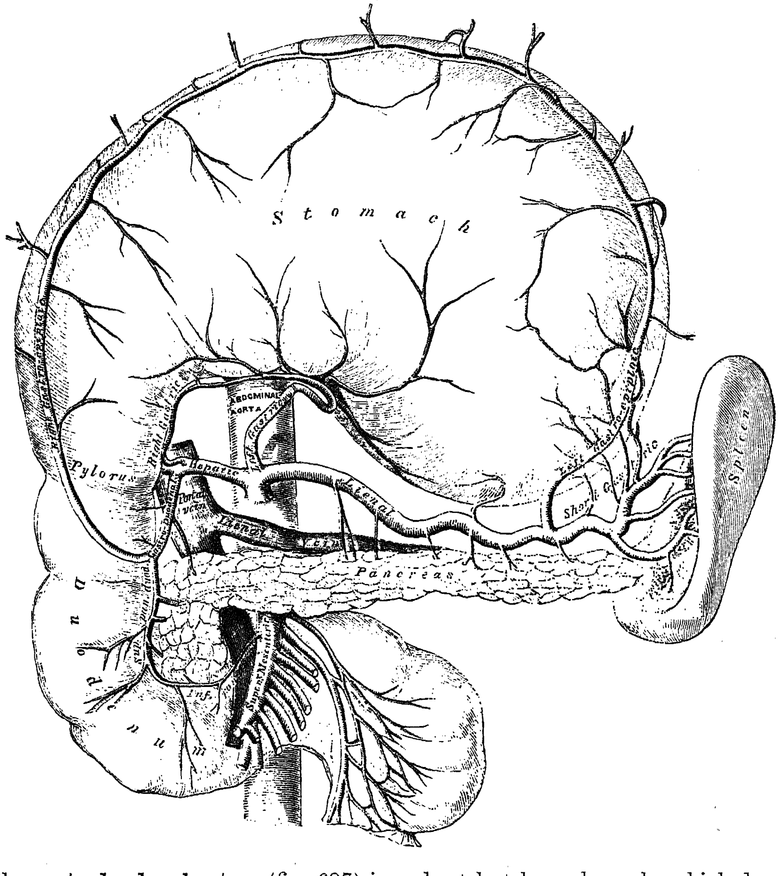
left of the bile-duct. The distribution of the hepatic artery within the liver is described with the anatomy of the liver, in the section on Splanchnology.

Its branches are:

Right gastric. Gastroduodenal. Cystic.

The **right gastric artery** (pyloric artery) (fig. 696) arises from the hepatic artery above the superior part of the duodenum; it descends in the lesser omentum to the pyloric end of the stomach, and passes from right to left along its lesser curvature, supplying it with branches, and anastomosing with the left gastric artery.

FIG. 697.—The cœliac artery and its branches; the stomach has been raised and the peritoneum removed.



The **gastroduodenal artery** (fig. 697) is a short but large branch, which descends, near the pylorus, between the superior part of the duodenum and the neck of the pancreas, and divides at the lower border of the duodenum into two branches, the *right gastro-epiploic* and the *superior pancreaticoduodenal* arteries. Previous to its division it gives off two or three small branches to the pyloric end of the stomach and to the pancreas.

The **right gastro-epiploic artery** (figs. 696, 697), the larger terminal branch of the gastroduodenal artery, runs from right to left along the greater curvature of the stomach, between the layers of the greater omentum, and ends by anastomosing with the left gastro-epiploic branch of the lienal artery. Except at the pylorus, where it is in contact with the stomach, it lies about a finger's breadth from the greater curvature. This vessel gives off numerous branches, some of which ascend to supply both surfaces of the stomach, while others descend in the greater omentum and anastomose with branches of the middle colic artery.

The **superior pancreaticoduodenal artery** (fig. 697) descends between the duodenum and the head of the pancreas. It supplies both these organs, and anastomoses

with the inferior pancreaticoduodenal branch of the superior mesenteric artery, and with the pancreatic branches of the lienal artery.

The **cystic artery** (fig. 696), usually a branch of the right hepatic artery, passes downwards and forwards along the neck of the gall-bladder, and divides into two branches, one of which ramifies on the free surface, the other on the attached surface of the gall-bladder.

3. The **lienal or splenic artery** (figs. 696, 697), the largest branch of the cœliac artery, is remarkable for the tortuosity of its course. Accompanied by the lienal vein which lies below it, it passes horizontally to the left, behind the stomach and the omental bursa of the peritoneum, and along the upper border of the pancreas; it then crosses in front of the left suprarenal gland and the upper part of the left kidney, and, on arriving near the spleen, divides into branches. Some of these branches enter the hilum of the spleen between the two layers of the lienorenal ligament; some are given to the pancreas, while others pass to the greater curvature of the stomach between the layers of the gastrolienal ligament. Its branches are:

Pancreatic. Short gastric.
Left gastro-epiploic.

The **pancreatic branches** (fig. 697) are numerous small vessels supplying the body and tail of the pancreas; they are derived from the lienal artery as it runs along the upper border of the pancreas. One branch, larger than the rest, is sometimes given off near the tail of the pancreas; it runs from left to right near the posterior surface of the gland, following the course of the pancreatic duct, and is called the *arteria pancreatica magna*. These vessels anastomose with the pancreatic branches of the superior and inferior pancreaticoduodenal arteries.

The **short gastric arteries** (vasa brevia) (fig. 697) consist of from five to seven small branches which arise from the end of the lienal artery, and from its terminal divisions. They pass from left to right, between the layers of the gastrolienal ligament, and are distributed to the greater curvature of the stomach, anastomosing with branches of the left gastric and left gastro-epiploic arteries.

The **left gastro-epiploic artery** (figs. 696, 697), the largest branch of the lienal artery, runs from left to right about a finger's breadth from the greater curvature of the stomach, between the layers of the greater omentum, and anastomoses with the right gastro-epiploic artery. It distributes several ascending branches to both surfaces of the stomach; others descend to supply the greater omentum and anastomose with branches of the middle colic artery.

Applied Anatomy.—Embolism of branches of the lienal artery is tolerably common in heart disease, the embolus coming from the left side of the heart. It is characterised by the occurrence of a sudden sharp pain or 'stitch' in the splenic region, with subsequent local enlargement of the spleen from the formation of an infarct in its substance.

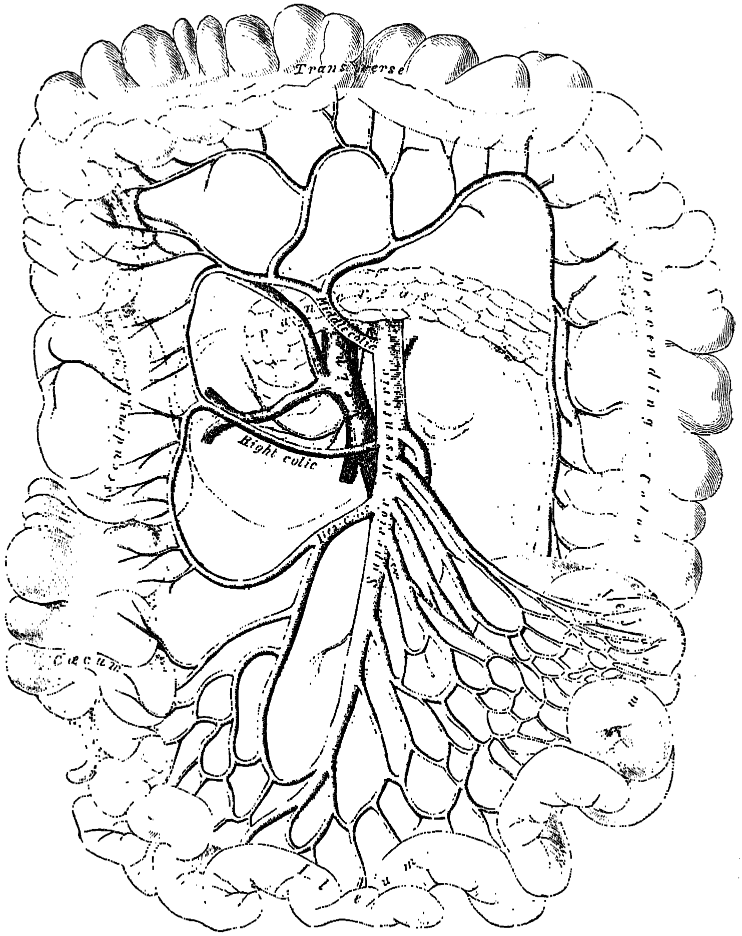
The Superior Mesenteric Artery (fig. 698)

The **superior mesenteric artery** supplies the whole of the small intestine except the superior part of the duodenum; it also supplies the cæcum and the ascending colon and about one-half of the transverse colon. It arises from the front of the aorta about 1 cm. below the cœliac artery, and is crossed at its origin by the lienal vein and the neck of the pancreas. It passes downwards and forwards, anterior to the processus uncinatus of the head of the pancreas and the horizontal part of the duodenum, and descends between the layers of the mesentery to the right iliac fossa, where, considerably diminished in size, it anastomoses with one of its own branches, viz. the ileocolic artery. In its course it crosses in front of the inferior vena cava, the right ureter, and Psoas major, and forms an arch, the convexity of which is directed forwards, downwards, and to the left side. It is accompanied by the superior mesenteric vein, which lies to its right side, and is surrounded by the superior mesenteric plexus of nerves. Its branches are:

Inferior pancreaticoduodenal. Ileocolic.
Jejunal and ileal. Right colic.
Middle colic.

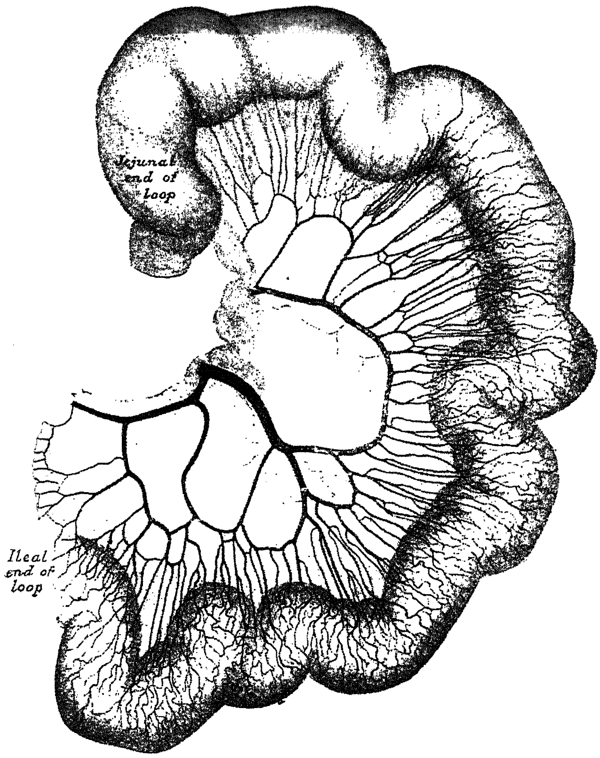
The **inferior pancreaticoduodenal artery** (fig. 697) springs from the superior mesenteric artery or from its first jejunal branch, opposite the upper border of the inferior part of the duodenum. It courses to the right between the head of the pancreas and duodenum, and then ascends to anastomose with the superior pancreaticoduodenal artery. It distributes branches to the head of the pancreas and to the descending, horizontal and ascending parts of the duodenum.

FIG. 698.—The superior mesenteric artery and its branches.



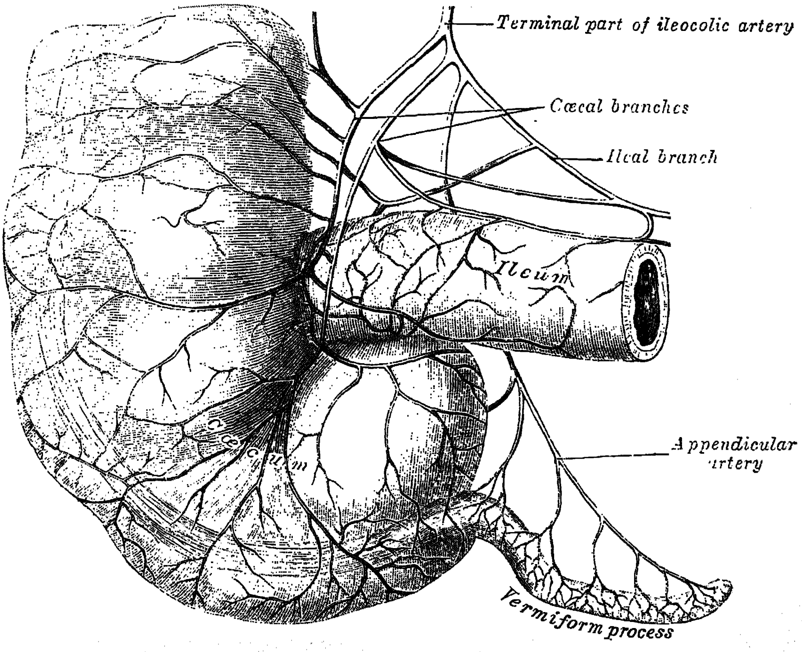
The **jejunal and ileal arteries** (vasa intestini tenuis) (fig. 698) arise from the left side of the superior mesenteric artery. They are usually from twelve to fifteen in number, and are distributed to the jejunum and ileum, with the exception of the terminal part of the latter which is supplied by the ileocolic artery. They run nearly parallel with one another between the layers of the mesentery, each vessel dividing into two branches, which unite with adjacent branches, to form a series of arches (fig. 699). From these arches branches arise and unite to form a second series of arches, and the process may be repeated three or four times. In the short, upper part of the mesentery only one set of arches exists, but as the mesentery increases in depth, second, third, fourth, and even fifth groups are present. From the terminal arches numerous small straight vessels arise which are distributed to the intestine. From the jejunal and ileal arteries small branches are given off to the lymph-glands and other structures between the layers of the mesentery.

FIG. 699.—A loop of the small intestine showing the distribution of the intestinal arteries. (From a preparation by Hamilton Drummond.)



The vessels were injected while the gut was *in situ* ; the gut was then removed, and an x-ray photograph taken.

FIG. 700.—The arteries of the cæcum and vermiform process.



The **ileocolic artery** (fig. 698) is the lowest of the branches arising from the concavity of the superior mesenteric artery. It passes downwards and to the right behind the peritoneum, towards the right iliac fossa, where it divides into a superior and an inferior branch; the superior branch anastomoses with the right colic artery, the inferior with the end of the superior mesenteric artery.

The inferior branch of the ileocolic runs towards the upper border of the ileocolic junction and supplies the following branches (fig. 700) : (*a*) *colic*, which pass upwards on the ascending colon; (*b*) *anterior and posterior cæcal*, which are distributed to the front and back of the cæcum; (*c*) an *appendicular artery*, which descends behind the termination of the ileum and enters the mesenteriole of the vermiform process; it runs near the free margin of this mesenteriole and ends in branches which supply the vermiform process; and (*d*) *ileal*, which runs upwards and to the left on the lower part of the ileum, and anastomoses with the termination of the superior mesenteric artery.

The **right colic artery** (fig. 698) arises from near the middle of the concavity of the superior mesenteric artery, or from a stem common to it and the ileocolic artery. It passes to the right behind the peritoneum, and in front of the right testicular (or ovarian) artery and vein, the right ureter, and the Psoas major, towards the ascending colon. Sometimes the vessel lies at a higher level, and crosses the descending part of the duodenum and the lower end of the right kidney. At the colon it divides into a descending branch, which anastomoses with the ileocolic artery, and an ascending branch, which anastomoses with the middle colic artery. These branches form arches, from the convexity of which vessels are distributed to the ascending colon.

The **middle colic artery** (fig. 698) arises from the superior mesenteric artery just below the pancreas and, passing downwards and forwards between the layers of the transverse mesocolon, divides into a right and a left branch ; the former anastomoses with the right colic artery; the latter with the left colic artery, a branch of the inferior mesenteric artery. The arches thus formed are placed about two fingers' breadth from the transverse colon, to which they distribute branches. Branches of the middle colic artery also anastomose with branches of the right and left gastro-epiploic arteries.

The Inferior Mesenteric Artery (fig. 701)

The **inferior mesenteric artery** supplies the left half of the transverse colon, the whole of the descending colon, the sigmoid colon, and the greater part of the rectum. It is smaller than the superior mesenteric artery, and arises from the aorta, about 3 or 4 cm. above its division into the common iliac arteries, and close to the lower border of the horizontal part of the duodenum. It descends behind the peritoneum, lying at first in front, and then on the left side of the aorta. It crosses the left common iliac artery on the medial side of the left ureter, and is continued into the lesser pelvis as the *superior hæmorrhoidal artery*, between the two layers of the sigmoid mesocolon, and ends on the upper part of the rectum. Its branches are :

Left colic. Sigmoid. Superior hæmorrhoidal.

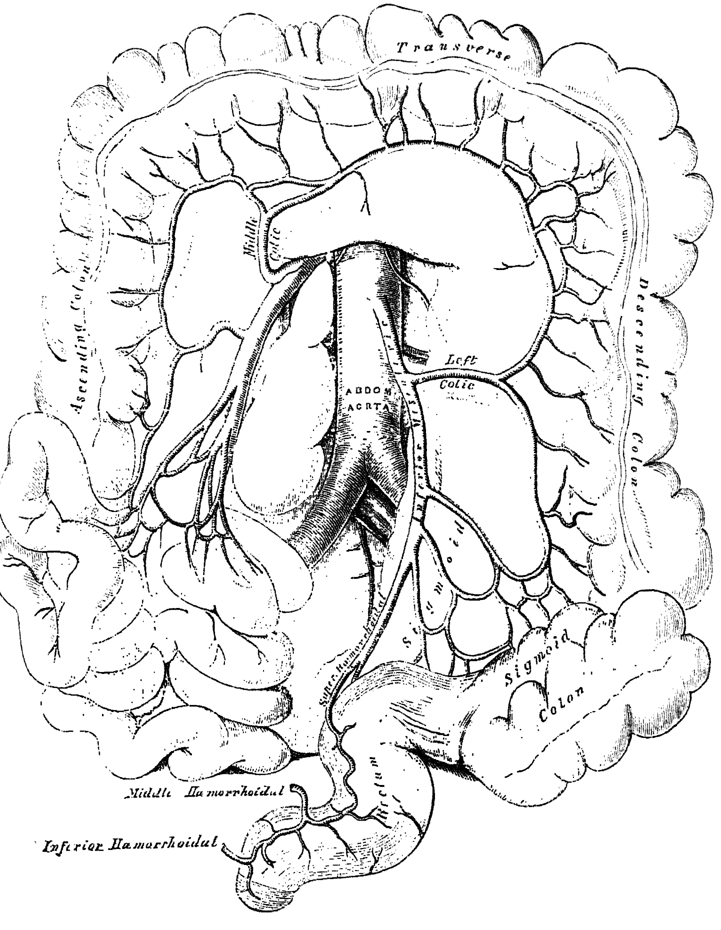
The **left colic artery** (fig. 701) runs to the left behind the peritoneum and in front of the Psoas major, and, after a short but variable course, divides into an ascending and a descending branch ; the trunk or the branches of the artery cross the left ureter and left testicular vessels. The ascending branch passes in front of the left kidney and then between the two layers of the transverse mesocolon where it anastomoses with the middle colic artery ; the descending branch anastomoses with the highest sigmoid artery. From the arches formed by these anastomoses branches are distributed to the descending colon and the left half of the transverse colon.

The **sigmoid arteries** (figs. 701, 702), two or three in number, run obliquely downwards and to the left behind the peritoneum and in front of the Psoas major, ureter, and testicular vessels. Their branches supply the lower part of the descending colon and the sigmoid colon, anastomosing above with the left colic artery, and below with the superior hæmorrhoidal artery.

The **superior hæmorrhoidal artery** (figs. 701, 702), the continuation of the inferior mesenteric artery, descends into the pelvis between the layers of the sigmoid mesocolon, crossing, in its course, the left common iliac vessels. It divides, opposite

the third sacral vertebra, into two branches; these descend one on either side of the rectum, and supply its mucous membrane as far as the anal canal, and the upper part of its muscular coat; about 10 or 12 cm. from the anus the two arteries break up into several small branches. These pierce the muscular coat of the bowel and run straight downwards in the wall of the gut between its muscular and mucous

FIG. 701.—The inferior mesenteric artery and its branches.



coats, to the level of the Sphincter ani internus; here they form a series of loops around the lower end of the rectum, and communicate with the middle hæmorrhoidal branches of the hypogastric artery, and with the inferior hæmorrhoidal branches of the internal pudendal artery.

Applied Anatomy.—Embolism of the mesenteric arteries produces acute and severe symptoms, of which the chief are abdominal pain and tenderness, nausea and vomiting, diarrhœa or constipation; blood is found in the stools of nearly half the patients. In many cases the symptoms closely resemble those of intestinal obstruction.

As a result of the free anastomoses between the left colic and sigmoid arteries a continuous "marginal artery" descends, near the gut, from the left colic flexure to the distal end of the sigmoid flexure, where it stops, because the superior hæmorrhoidal artery does not divide into arch-forming branches. The point where the lowest sigmoid artery anastomoses with the superior hæmorrhoidal artery is therefore sometimes named the "critical point." Ligature of these two arteries will almost certainly result in gangrene of the part of the rectum which is supplied by them. If, however, the inferior mesenteric artery be tied proximal to the origin of its lowest sigmoid branch, blood can pass through the latter branch into the superior hæmorrhoidal artery.

The Middle Suprarenal Arteries

The **middle suprarenal arteries** are two small vessels which arise, one from either side of the aorta, opposite the superior mesenteric artery. Each passes lateralwards and slightly upwards, over the crus of the Diaphragm, to the suprarenal gland, where it anastomoses with suprarenal branches of the inferior phrenic and renal arteries.

The Renal Arteries (fig. 695)

The **renal arteries** are two large trunks, which arise from the sides of the aorta, immediately below the superior mesenteric artery. Each is directed across the crus of the Diaphragm, so as to form nearly a right angle with the aorta. The *right* is longer than the left, on account of the position of the aorta; it passes behind the inferior vena cava, the right renal vein, the head of the pancreas, and the descending part of the duodenum. The *left* is a little higher than the right; it lies behind the left renal vein, the body of the pancreas and the lienal vein, and is crossed by the inferior mesenteric vein. Before reaching the hilum of the kidney, each artery divides into four or five branches; most of these lie between the renal vein and renal pelvis, the vein being in front, the pelvis behind, but one or more branches are usually situated behind the pelvis. Each vessel gives off some small *inferior suprarenal branches* to the suprarenal gland, and supplies twigs to the ureter and the surrounding cellular tissue and muscles.

One or two accessory renal arteries are frequently found, more especially on the left side: they usually arise from the aorta, and may come off above or below the main artery, the former being the more common position. Instead of entering the kidney at the hilum, they usually pierce the upper or lower part of the kidney; an accessory artery to the lower part of the kidney crosses in front of the ureter.

The Testicular Arteries (fig. 695)

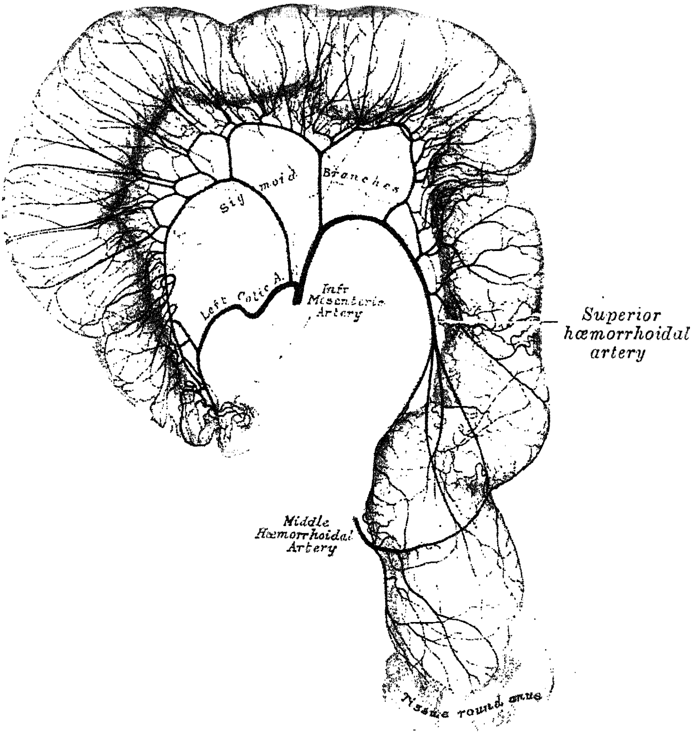
The **testicular arteries** (internal spermatic arteries) are two long slender vessels which arise from the front of the aorta a little below the renal arteries. Each passes obliquely downwards and lateralwards behind the peritoneum, resting on the Psoas major; the right artery lies in front of the inferior vena cava and behind the right colic and ileocolic arteries and the terminal part of the ileum; the left artery passes behind the left colic and sigmoid arteries, and the iliac part of the descending colon. Each artery crosses obliquely over the ureter and the lower part of the external iliac artery to reach the abdominal inguinal ring, through which, accompanied by the other constituents of the spermatic cord, it enters the inguinal canal and passes to the scrotum, where it becomes tortuous and divides into several branches. Two or three of these accompany the ductus deferens, and supply the epididymis, anastomosing with the artery of the ductus deferens; others pierce the back part of the tunica albuginea, and supply the substance of the testis. The testicular artery supplies one or two small branches to the ureter, and in the inguinal canal gives one or two twigs to the Cremaster.

The Ovarian Arteries

The **ovarian arteries** in the female correspond to the testicular arteries in the male. They supply the ovaries, are shorter than the testicular arteries, and end in the pelvic cavity. The origin and course of the first part of each artery are the same as those of the testicular artery, but on arriving at the upper opening of the lesser pelvis the artery passes medialwards between the two layers of the broad ligament of the uterus below the uterine tube. At the level of the ovary it runs backwards in the mesovarium and breaks up into branches which are distributed to the ovary. Small branches are

given to the ureter and the uterine tube, and one passes on to the side of the uterus, and unites with the uterine artery. Other offsets are continued on the round ligament of the uterus, through the inguinal canal, to the skin of the labium majus and the groin.

FIG. 702.—The sigmoid colon and rectum, showing the distribution of the branches of the inferior mesenteric artery, and their anastomoses. (From a preparation by Hamilton Drummond.)



At an early period of fœtal life, when the testes or ovaries lie by the side of the vertebral column, below the kidneys, the testicular and ovarian arteries are short; but with the descent of the testicles into the scrotum, and of the ovaries into the pelvis, the arteries are gradually lengthened.

THE INFERIOR PHRENIC ARTERIES (fig. 695)

The **inferior phrenic arteries** are two small vessels which supply the Diaphragm. They present much variety in their origins; they may arise separately from the front of the aorta, immediately above the cœliac artery, or by a common trunk, which may spring either from the aorta or from the cœliac artery; sometimes one artery is derived from the aorta, and the other from one of the renal arteries. They diverge from one another across the crura of the Diaphragm, and then run obliquely upwards and lateralwards upon its under surface. The left phrenic passes behind the œsophagus, and runs forwards on the left side of the œsophageal hiatus. The right phrenic passes behind the inferior vena cava, and along the right side of the foramen which transmits that vein. Near the posterior border of the central tendon of the Diaphragm each vessel divides into a medial and a lateral branch. The medial

branch curves forwards, and anastomoses with its fellow of the opposite side, and with the musculophrenic and pericardiacophrenic arteries. The lateral branch passes towards the side of the thorax, and anastomoses with the lower intercostal arteries, and with the musculophrenic artery. The lateral branch of the right artery gives off a few twigs to the inferior vena cava ; and the left artery sends some branches to the œsophagus. Each vessel gives off *superior suprarenal branches* to the suprarenal gland of its own side. The liver and the spleen also receive a few twigs from the right and left vessels respectively.

The Lumbar Arteries

The **lumbar arteries** are in series with the intercostal arteries. Usually four in number on either side, they arise from the back of the aorta, opposite the bodies of the upper four lumbar vertebræ. A fifth pair, small in size, occasionally arises from the middle sacral artery ; but the lumbar branches of the iliolumbar arteries usually take the place of the fifth pair. The lumbar arteries run lateralwards and backwards on the bodies of the lumbar vertebræ, behind the sympathetic trunk, to the intervals between the adjacent transverse processes, and are then continued into the abdominal wall. The arteries of the right side pass behind the inferior vena cava, and the upper two on either side run behind the corresponding crus of the Diaphragm. The arteries of both sides pass beneath the tendinous arches which give origin to the Psoas major, and are continued behind this muscle and the lumbar plexus. They then cross the Quadratus lumborum, the upper three arteries running behind, the last usually in front of it. At the lateral border of the Quadratus lumborum they pierce the posterior aponeurosis of the Transversus abdominis, and are carried forwards between this muscle and the Obliquus internus. They anastomose with one another and with the lower intercostal, subcostal, iliolumbar, deep iliac circumflex, and inferior epigastric arteries.

Branches.—Each lumbar artery gives off a *posterior ramus* which, passing backwards between the transverse processes, is distributed to the muscles and skin of the back. The posterior ramus also furnishes a *spinal branch* which enters the vertebral canal and supplies its contents, anastomosing with the arteries above and below it, and with the artery of the opposite side. Branches are also given by the lumbar arteries and their posterior rami to the neighbouring muscles.

The Middle Sacral Artery (fig. 695)

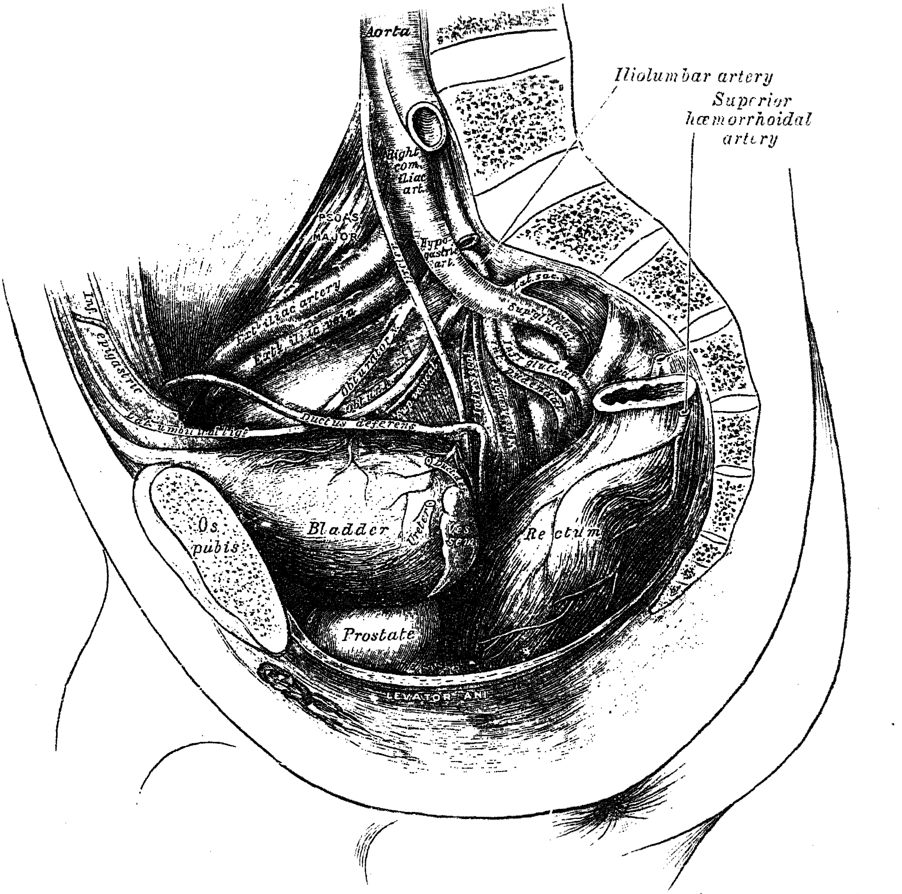
The **middle sacral artery** is a small vessel, which arises from the back of the aorta, a little above its bifurcation. It descends in the middle line in front of the fourth and fifth lumbar vertebræ, the sacrum and coccyx, and ends in the glomus coccygeum (coccygeal gland). At the level of the fifth lumbar vertebra it is crossed by the left common iliac vein, and it frequently gives off on either side a small lumbar artery (*arteria lumbalis ima*). Minute branches are said to pass from it to the posterior surface of the rectum. On the last lumbar vertebra it anastomoses with the lumbar branch of the iliolumbar artery ; in front of the sacrum it anastomoses with the lateral sacral arteries, and sends offsets into the anterior sacral foramina.

The Common Iliac Arteries (figs. 695, 703)

The abdominal aorta divides, on the left side of the body of the fourth lumbar vertebra, into the two **common iliac arteries** which diverge from the termination of the aorta, pass downwards and lateralwards, and divide opposite the fibrocartilage between the last lumbar vertebra and the sacrum, into two branches, the *external iliac* and *hypogastric arteries* : the former supplies the greater part of the lower extremity ; the latter, the viscera and parietes of the pelvis, and the glutæal region.

The **right common iliac artery** (figs. 695, 703), about 5 cm. long, passes obliquely across the body of the last lumbar vertebra. *In front* of it are the peritoneum, the small intestine, branches of the sympathetic nerves, and, at its point of division, the ureter. *Behind*, it is separated from the bodies of the fourth and fifth lumbar vertebræ and the intervening fibrocartilage by the terminations of the two common iliac veins and the commencement of the inferior vena cava. *Laterally*, it is in relation, above, with the inferior vena cava and the right common iliac vein; below, with the Psoas major. *Medial* to it, above, is the left common iliac vein.

FIG. 703.—The arteries of the pelvis. Right side.



The **left common iliac artery** (695), about 4 cm. long, is in relation, *in front* with the peritoneum, the small intestine, branches of the sympathetic nerves, and the superior hæmorrhoidal artery, and is crossed at its point of bifurcation by the ureter. It rests on the bodies of the fourth and fifth lumbar vertebræ, and the intervening fibrocartilage. The left common iliac vein lies partly *medial* to, and partly *behind*, the artery; *laterally*, the artery is in relation with the Psoas major.

Branches.—The common iliac arteries give off small branches to the peritoneum, Psoas major, ureters, and the surrounding areolar tissue, and occasionally give origin to the iliolumbar or to the accessory renal arteries.

Peculiarities.—The points of origin of the common iliac arteries vary according to the bifurcation of the aorta, which in most cases occurs either upon the fourth lumbar vertebra, or upon the fibrocartilage between it and the fifth.

The common iliac arteries may divide above or below the usual level.

The length of the arteries varies from 3·5 to 7·5 cm. In rare instances, the right common iliac has been found wanting, the external iliac and hypogastric arteries arising directly from the aorta.

Applied Anatomy.—The easiest and best method of tying the common iliac artery is by a transperitoneal route. The abdomen is opened, the intestines are drawn aside, the peritoneum covering the artery divided and the ureter carefully identified; the sheath of the artery is then opened, and the needle passed from the medial to the lateral side. On the right side great care must be exercised in passing the needle, since both the common iliac veins lie behind the artery.

Collateral Circulation.—The principal agents in carrying on the collateral circulation after the application of a ligature to the common iliac are: the anastomoses of the hæmorrhoidal branches of the hypogastric artery with the superior hæmorrhoidal branches from the inferior mesenteric artery; of the uterine, ovarian, and vesical arteries of the opposite sides; of the lateral sacral arteries with the middle sacral artery; of the inferior epigastric artery with the internal mammary, lower intercostal, and lumbar arteries; of the deep iliac circumflex artery with the lumbar arteries; of the iliolumbar artery with the last lumbar artery; of the obturator artery, by means of its pubic branch, with the vessel of the opposite side and with the inferior epigastric artery.

The Hypogastric Artery (fig. 703)

The **hypogastric or internal iliac artery**, about 4 cm. long, arises at the bifurcation of the common iliac artery, opposite the lumbosacral articulation; it descends to the upper margin of the greater sciatic foramen where it divides into an *anterior* and a *posterior* trunk.

Relations.—It is in relation *in front* with the ureter; *behind*, with the internal iliac vein, the lumbosacral nerve-trunk, and the Piriformis; *laterally*, near its origin, with the external iliac vein, which lies between it and the Psoas major; lower down, with the obturator nerve.

In the fœtus, the hypogastric artery is twice as large as the external iliac artery, and is the direct continuation of the common iliac artery. It ascends on the back of the anterior wall of the abdomen to the umbilicus, converging towards its fellow of the opposite side. Having passed through the umbilical opening, the two arteries, now termed *umbilical*, enter the umbilical cord, where they are coiled round the umbilical vein, and ultimately ramify in the placenta.

At birth, when the placental circulation ceases, the pelvic portion only of the artery remains patent and constitutes the hypogastric artery and the first part of the superior vesical artery of the adult; the remainder of the vessel is converted into a fibrous cord, the *lateral umbilical ligament* (obliterated hypogastric artery), which extends from the pelvis to the umbilicus.

Peculiarities.—The lengths of the hypogastric and common iliac arteries bear an inverse proportion to each other.

The place of division of the hypogastric artery varies between the upper margin of the sacrum and the upper border of the greater sciatic foramen.

Applied Anatomy.—For the application of a ligature to the hypogastric artery the vessel is best secured by an abdominal section in the median line, the vessel being reached through the peritoneal cavity. It should be remembered that the vein lies behind, and, on the right side, a little lateral to the artery; the ureter lies in front of it.

Collateral Circulation.—The circulation after ligature of the hypogastric artery is carried on by the anastomoses of the uterine and ovarian arteries; of the vesical arteries of the two sides; of the hæmorrhoidal branches of the hypogastric artery with those from the inferior mesenteric artery; of the pubic branch of the obturator artery with the vessel of the opposite side, and with the inferior epigastric and medial femoral circumflex arteries; of the circumflex and perforating branches of the arteria profunda femoris with the inferior glutæal artery; of the superior glutæal artery with the posterior branches of the lateral sacral arteries; of the iliolumbar with the last lumbar artery; of the middle sacral arteries with the lateral sacral artery; and of the iliac circumflex with the iliolumbar and superior glutæal arteries.*

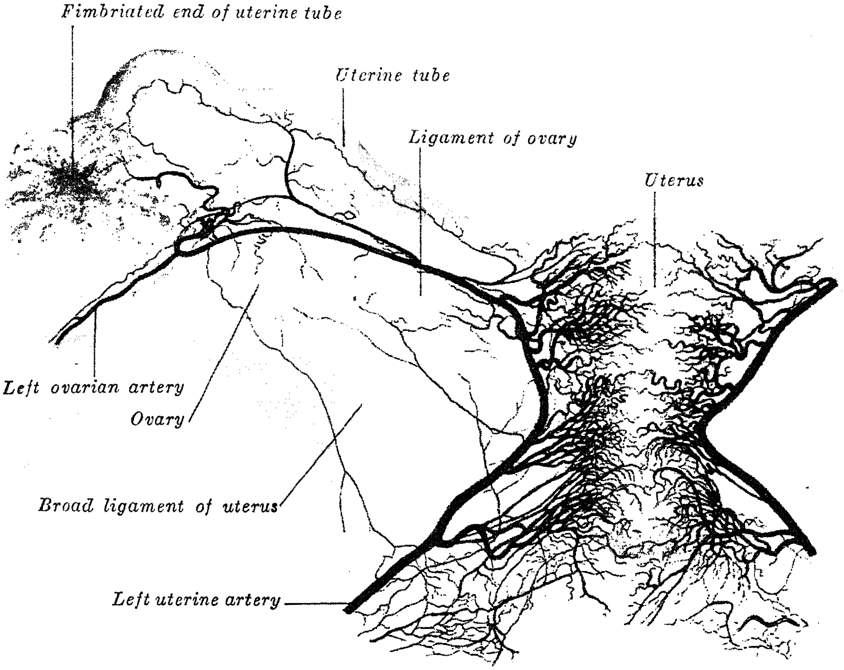
* For a description of a case in which Owen made a dissection ten years after ligature of the hypogastric artery, see *Med.-Chir. Trans.* vol. xvi.

The branches of the hypogastric artery are:

From the Anterior Trunk.	*From the Posterior Trunk.*
Superior vesical.	Iliolumbar.
Inferior vesical.	Lateral sacral.
Middle hæmorrhoidal.	Superior glutæal.
Uterine. } *In the female.*	
Vaginal. }	
Obturator.	
Internal pudendal.	
Inferior glutæal.	

The **superior vesical artery** (fig. 703) supplies numerous branches to the upper part of the bladder. From one of these a slender vessel, the *artery to the ductus deferens*, takes origin and accompanies the ductus deferens in its course to the testis, where it anastomoses with the testicular artery. Other branches supply the ureter. The first part of the superior vesical artery is the proximal, pervious portion of the fœtal hypogastric artery.

FIG. 704.—The left uterine and ovarian arteries of an unmarried girl aged $17\frac{1}{2}$ years. Posterior aspect. (From a preparation by Hamilton Drummond.)



The **inferior vesical artery** (fig. 703) frequently arises in common with the middle hæmorrhoidal artery, and is distributed to the fundus of the bladder, the prostate, the vesiculæ seminales and the lower part of the ureter. The branches to the prostate communicate with the corresponding vessels of the opposite side.

The **middle hæmorrhoidal artery** (figs. 702, 703) usually arises with the preceding vessel. It is distributed to the muscular coats of the rectum, anastomosing with the inferior vesical artery and with the superior and inferior hæmorrhoidal arteries. It gives offsets to the vesiculæ seminales and prostate.

The **uterine artery** (fig. 704) runs medialwards on the Levator ani and towards the cervix uteri; about 2 cm. from the cervix it crosses above and in front of the ureter, to which it supplies a small branch. Reaching the side of the uterus it ascends in a tortuous manner between the two layers of the broad ligament to the junction of the uterine tube and uterus. It then runs lateralwards towards the hilum of the ovary, and ends by joining with the ovarian artery. It supplies

branches to the cervix uteri and others which descend on the vagina ; the latter anastomose with branches of the vaginal arteries and form with them two median longitudinal vessels—the *azygos arteries of the vagina*—one of which descends in front of, and the other behind, the vagina. It supplies numerous branches to the body of the uterus, and from its terminal portion twigs are distributed to the uterine tube and the round ligament of the uterus.

The **vaginal artery** usually corresponds to the inferior vesical in the male ; it descends upon the vagina, supplying its mucous membrane, and sends branches to the bulb of the vestibule, the fundus of the bladder, and the contiguous part of the rectum. It assists in forming the azygos arteries of the vagina, and is frequently represented by two or three branches.

The **obturator artery** (fig. 703) passes forwards and downwards on the lateral wall of the pelvis, to the upper part of the obturator foramen, and, escaping from the pelvic cavity through the obturator canal, divides into an anterior and a posterior branch. In the pelvic cavity this vessel is in relation, laterally, with the obturator fascia, which separates it from the Obturator internus muscle ; medially, with the ureter, ductus deferens, and peritoneum ; the obturator nerve is above it, and the obturator vein below it.

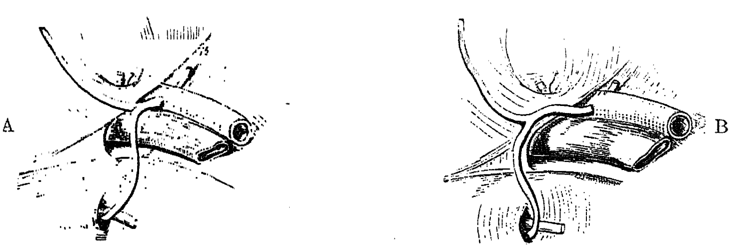
Branches.—*Inside the pelvis,* the obturator artery gives off (*a*) **iliac branches** to the iliac fossa ; these supply the bone and the Iliacus, and anastomose with the iliolumbar artery ; (*b*) a **vesical branch** which runs medialwards to the bladder and may replace the inferior vesical branch of the hypogastric artery ; and (*c*) a **pubic branch** which springs from the vessel just before it leaves the pelvic cavity ; this branch ascends upon the back of the os pubis and anastomoses with the corresponding vessel of the opposite side, and with the pubic branch of the inferior epigastric artery.

Outside the pelvis, the obturator artery divides at the upper margin of the obturator foramen, into an anterior and a posterior branch which encircle the foramen under cover of the Obturator externus.

The **anterior branch** runs forwards on the outer surface of the obturator membrane and then curves downwards along the anterior margin of the foramen. It supplies branches to the Obturator externus, Pectineus, Adductores, and Gracilis, and anastomoses with the posterior branch, and with the medial femoral circumflex artery.

The **posterior branch** follows the posterior margin of the foramen and turns forwards on the inferior ramus of the ischium where it anastomoses with the anterior branch. It gives twigs to the muscles attached to the ischial tuberosity and anastomoses with the inferior glutæal artery. It also supplies an articular branch which enters the hip-joint through the acetabular notch, ramifies in the fat at the bottom of the acetabulum, and sends a twig along the ligamentum teres to the head of the femur.

FIG. 705.—Variations in the course of an abnormal obturator artery.



Peculiarities.—In about 28 per cent. of subjects the place of the obturator artery is taken by an enlarged pubic branch of the inferior epigastric artery (p. 686) ; this branch descends almost vertically to the upper part of the obturator foramen. The artery usually lies in contact with the external iliac vein, and on the lateral side of the femoral ring (fig. 705A) ; in such cases it would not be endangered in the operation for strangulated femoral hernia. Occasionally, however, it curves along the free margin of the lacunar ligament (fig. 705B), and if in such circumstances a femoral hernia occurred, the vessel would almost completely encircle the neck of the hernial sac, and would be in great danger of being wounded if an operation were performed for strangulation. It sometimes arises from the main stem or from the posterior trunk of the hypogastric artery, or it may spring from the superior glutæal artery : occasionally it arises from the external iliac artery.

The **internal pudendal artery** (figs. 703, 706, 707), the smaller of the two terminal branches of the anterior trunk of the hypogastric artery, supplies the external

organs of generation. Though the course of the artery is the same in the two sexes, the vessel is smaller in the female than in the male, and the distribution of its branches somewhat different. The description of the artery in the male will first be given, and subsequently the differences which it presents in the female will be mentioned.

The **internal pudendal artery in the male** passes downwards and lateralwards to the lower border of the greater sciatic foramen, and emerges from the pelvis between the Piriformis and Coccygeus; it then crosses the ischial spine, and enters the perinæum through the lesser sciatic foramen. The artery now crosses the Obturator internus, along the lateral wall of the ischiorectal fossa, being situated about 4 cm. above the lower margin of the ischial tuberosity. It gradually approaches the margin of the inferior ramus of the ischium and passes forwards between the two layers of the fascia of the urogenital diaphragm; it then runs forwards along the medial margin of the inferior ramus of the os pubis, and at a distance of about 1·25 cm. behind the pubic arcuate ligament it pierces the inferior fascia of the urogenital diaphragm and divides into the *dorsal* and *deep arteries of the penis*.

Relations.—Within the pelvis, it lies in front of the Piriformis, the sacral plexus of nerves, and the inferior glutæal artery. As it crosses the ischial spine, it is covered by the Glutæus maximus; here the pudendal nerve lies to the medial side, and the nerve to the Obturator internus to the lateral side, of the vessel. In the perinæum it lies on the lateral wall of the ischiorectal fossa in a fascial canal (*Alcock's canal*); it is accompanied by a pair of venæ comitantes and the pudendal nerve.

Branches.—The branches of the internal pudendal artery (figs. 706, 707) are:

Muscular.	Artery of the urethral bulb.
Inferior hæmorrhoidal.	Urethral.
Perinæal.	Deep artery of the penis.
Dorsal artery of the penis.	

The **muscular branches** consist of two sets; one given off in the pelvis; the other, as the vessel crosses the ischial spine. The first set consists of several small offsets which supply the Levator ani, the Obturator internus, the Piriformis, and the Coccygeus. The branches of the second set are distributed to the Glutæus maximus and the external rotator muscles of the thigh; they anastomose with branches of the inferior glutæal artery.

The **inferior hæmorrhoidal artery** arises from the internal pudendal as it passes above the ischial tuberosity. Piercing the wall of Alcock's canal it divides into two or three branches which cross the ischiorectal fossa, and are distributed to the muscles and skin of the anal region, and send offshoots round the lower edge of the Glutæus maximus to the skin of the buttock. They anastomose with the corresponding vessels of the opposite side, with the superior and middle hæmorrhoidal arteries, and with the perinæal artery.

The **perinæal artery** arises from the internal pudendal artery, in front of the preceding branches, crosses either superficial or deep to the Transversus perinæi superficialis, and runs forwards in the interspace between the Bulbocavernosus and Ischiocavernosus, to both of which it supplies branches, and finally divides into several **posterior scrotal branches** which are distributed to the skin and dartos tunic of the scrotum. As it crosses the Transversus perinæi superficialis it gives off the **transverse perinæal artery** which runs transversely on the cutaneous surface of the muscle, and anastomoses with the corresponding vessel of the opposite side and with the perinæal and inferior hæmorrhoidal arteries. It supplies the Transversus perinæi superficialis and the structures between the anus and the urethral bulb.

The **artery of the urethral bulb** is a short vessel of relatively large calibre which arises from the internal pudendal artery between the two layers of the fascia of the urogenital diaphragm; it passes medialwards, pierces the inferior fascia of the urogenital diaphragm, and gives off branches which ramify in the bulb of the urethra and in the posterior part of the corpus cavernosum urethræ. It supplies a small branch to the bulbo-urethral gland.

The **urethral artery** arises a short distance in front of the artery of the urethral bulb. It runs forwards and medialwards, pierces the inferior fascia of the urogenital diaphragm and enters the corpus cavernosum urethræ, in which it is continued forwards to the glans penis.

The **deep artery of the penis** (artery of the corpus cavernosum penis), one of the terminal branches of the internal pudendal artery, arises from that vessel while it is situated between the two fasciæ of the urogenital diaphragm; it pierces the inferior fascia, and, entering the crus penis obliquely, runs forwards in the centre of the corpus cavernosum penis close to the septum.

The **dorsal artery of the penis** ascends between the crus penis and the pubic symphysis, and, piercing the inferior fascia of the urogenital diaphragm, passes between the two layers of the suspensory ligament of the penis, and runs forwards on the dorsum of the penis to the glans, where it divides into two branches which supply the glans and prepuce. On the penis, it lies between the dorsal nerve and deep dorsal vein, the former being on its lateral side. It supplies the skin and the fibrous sheath of the corpus cavernosum penis, sending branches through the sheath to anastomose with the deep artery of the penis.

The **internal pudendal artery in the female** is smaller than in the male. Its origin and course are similar, and there is considerable analogy in the distribution of its branches. The perinæal artery supplies the labia pudendi; the artery of the bulb is distributed to the bulbus vestibuli and the erectile tissue of the vagina; the deep artery of the clitoris supplies the corpus cavernosum clitoridis; the dorsal artery of the clitoris gives branches to the dorsum of that organ, and ends in the glans and prepuce of the clitoris.

Peculiarities.—The internal pudendal artery is sometimes relatively small, or fails to give off one or two of its usual branches; in such cases the deficiency is supplied by branches derived from an additional vessel, the *accessory pudendal*, which generally arises from the internal pudendal artery before its exit from the greater sciatic foramen. It passes forwards along the lower part of the bladder and across the side of the prostate to the root of the penis, where it perforates the urogenital diaphragm, and gives off the branches usually derived from the internal pudendal artery. The deficiency most frequently met with is that in which the internal pudendal artery ends as the artery of the urethral bulb, the dorsal and deep arteries of the penis being derived from the accessory pudendal artery. The internal pudendal artery may also end as the perinæal, the artery of the urethral bulb being derived, with the other two branches, from the accessory vessel. Occasionally the accessory pudendal artery is derived from one of the other branches of the hypogastric artery, most frequently the inferior vesical or the obturator.

The **inferior glutæal artery** (sciatic artery) (figs. 703, 708), the larger of the two terminal branches of the anterior trunk of the hypogastric artery, is distributed chiefly to the buttock and the back of the thigh. It passes down on the sacral plexus of nerves and the Piriformis, behind the internal pudendal artery, to the lower part of the greater sciatic foramen, through which it escapes from the pelvis between the first and second sacral nerves, and between the Piriformis and Coccygeus. It then descends in the interval between the greater trochanter of the femur and the tuberosity of the ischium, accompanied by the sciatic and posterior femoral cutaneous nerves, and covered by the Glutæus maximus; it is continued down the back of the thigh, supplying the skin, and anastomosing with branches of the perforating arteries.

Branches.—*Inside the pelvis.* It distributes (*a*) branches to the Piriformis, Coccygeus, and Levator ani; (*b*) branches supplying the fat around the rectum, and which occasionally take the place of the middle hæmorrhoidal artery; and (*c*) vesical branches to the fundus of the bladder, vesiculæ seminales, and prostate.

Outside the pelvis.—**Muscular branches** supply the Glutæus maximus, the external rotators of the thigh, and the muscles attached to the tuberosity of the ischium; they anastomose with the superior glutæal, internal pudendal, obturator and medial femoral circumflex arteries.

Coccygeal branches run medialwards, pierce the sacrotuberous ligament, and supply the Glutæus maximus and the structures on the back of the coccyx.

The **arteria comitans nervi ischiadici**, a long slender vessel, accompanies the sciatic nerve for a short distance; it then penetrates it, and runs in its substance to the lower part of the thigh.

An **anastomotic branch**, directed obliquely downwards across the external rotator muscles of the thigh, assists in forming the so-called *cruciate anastomosis* by joining with the first perforating and the medial and lateral femoral circumflex arteries.

An **articular branch**, generally derived from the anastomotic, is distributed to the capsule of the hip-joint.

Cutaneous branches are distributed to the skin of the buttock and back of the thigh.

The **iliolumbar artery** (fig. 703), a branch of the posterior trunk of the hypogastric artery, runs upwards and lateralwards, in front of the sacro-iliac joint and the lumbosacral trunk, and behind the obturator nerve and the external iliac vessels, to the medial border of the Psoas major, behind which it divides into a lumbar and an iliac branch.

FIG. 706.—The superficial branches of the internal pudendal artery, in the male.

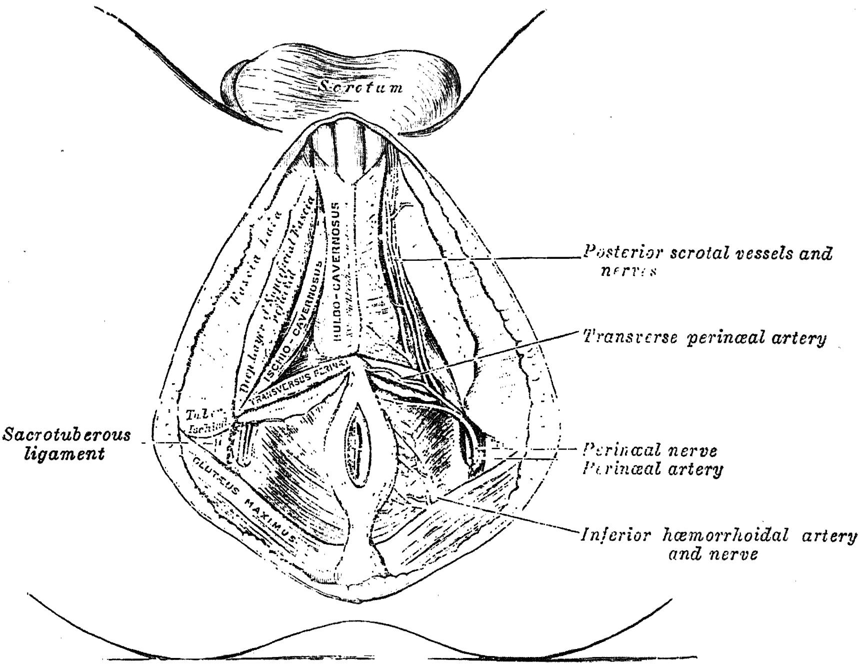
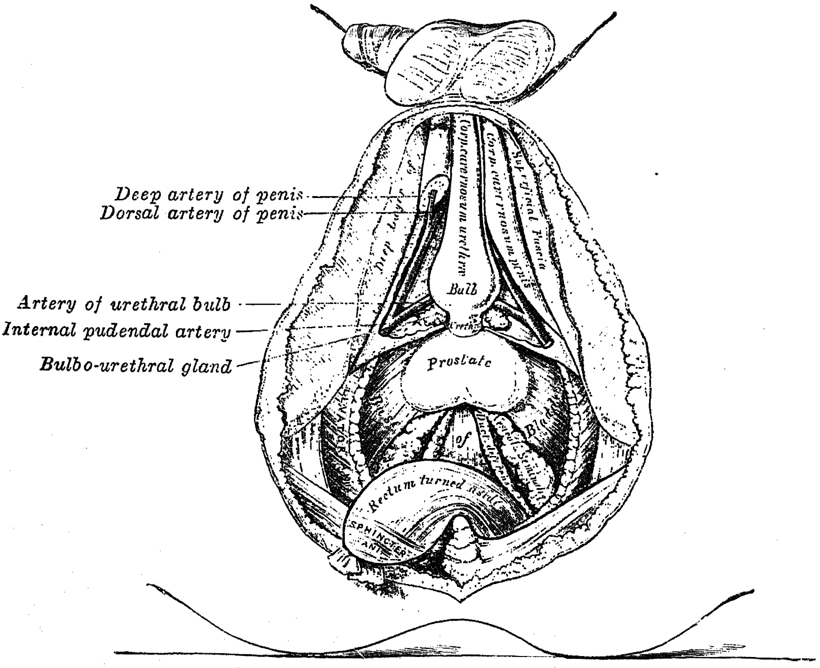


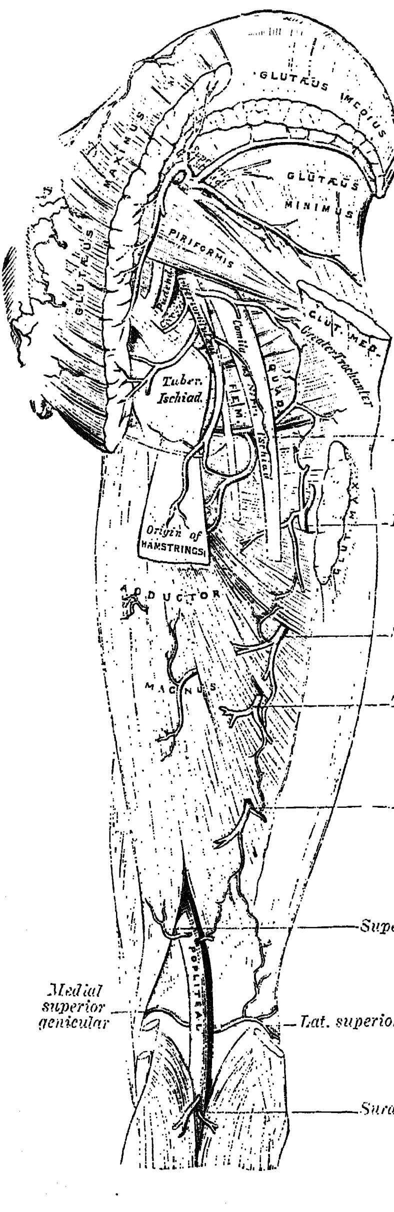
FIG. 707.—The deeper branches of the internal pudendal artery, in the male.



The **lumbar branch** supplies the Psoas major and Quadratus lumborum, anastomoses with the fourth lumbar artery, and sends a small *spinal branch* through the intervertebral foramen between the fifth lumbar vertebra and the base of the sacrum, into the vertebral canal to supply the cauda equina.

The **iliac branch** supplies the Iliacus; some offsets run between the muscle and the bone and anastomose with the iliac branches of the obturator artery; one of these enters an oblique canal to supply the bone, while others run along the crest of the ilium, distributing branches to the glutæal and abdominal muscles, and anastomoses in their course with the superior glutæal, iliac circumflex, and lateral femoral circumflex arteries.

FIG. 708.—The arteries of the glutæal and posterior femoral regions.



The **lateral sacral arteries** (fig. 703) arise from the posterior division of the hypogastric artery; there are usually two, a superior and an inferior. The *superior* and larger passes medialwards, and, after anastomosing with branches from the middle sacral artery, enters the first or second anterior sacral foramen, supplies branches to the contents of the sacral canal, and, escaping by the corresponding posterior sacral foramen, is distributed to the skin and muscles on the dorsum of the sacrum, anastomosing with the superior glutæal artery. The *inferior* runs obliquely across the front of the Piriformis and the sacral nerves, to the medial side of the anterior sacral foramina, descends on the front of the sacrum, and anastomoses over the coccyx with the middle sacral artery and the opposite lateral sacral arteries. Branches from this vessel enter the anterior sacral foramina, and, after supplying the contents of the sacral canal, escape by the posterior sacral foramina, and are distributed to the muscles and skin on the dorsal surface of the sacrum, anastomosing with the glutæal arteries.

The **superior glutæal artery** (figs. 703, 708) is the largest branch of the hypogastric artery, and appears to be the continuation of the posterior division of that vessel. It is a short artery which runs backwards between the lumbosacral trunk and the first sacral nerve, and, passing out of the pelvis through the upper part of the greater sciatic foramen above the upper border of the piriformis divides into a *superficial* and a *deep branch*. Within the pelvis it gives off a few branches to the Iliacus, Piriformis, and Obturator internus, and a nutrient artery to the hip-bone.

The *superficial branch* enters the deep surface of the Glutæus maximus, and divides into numerous branches; some of these supply the muscle and anastomose

with the inferior glutæal artery; others perforate the tendinous origin of the muscle, supply the skin covering the posterior surface of the sacrum, and anastomose with the posterior branches of the lateral sacral arteries.

The *deep branch* lies under the Glutæus medius and soon splits into a superior and an inferior division. The *superior division* runs along the upper border of the Glutæus minimus to the anterior superior iliac spine, anastomosing with the deep iliac circumflex artery and the ascending branch of the lateral femoral circumflex artery. The *inferior division* crosses the Glutæus minimus obliquely to the greater trochanter, distributes branches to this muscle and to the Glutæus medius, and anastomoses with the lateral femoral circumflex artery; some branches pierce the Glutæus minimus and supply the hip-joint.

Applied Anatomy.—The *superior glutæal artery* is ligatured by turning the patient two-thirds over on to his face and making an incision from the posterior superior spine of the ilium to the upper and posterior angle of the greater trochanter. This exposes the Glutæus maximus, and its fibres are to be separated through the whole thickness of the muscle and pulled apart with retractors. The contiguous margins of the Glutæus medius and Piriformis are now to be separated from each other, and the artery will be exposed emerging from the greater sciatic foramen. In ligature of the *inferior glutæal artery*, the incision should be made parallel with that for ligature of the superior glutæal but 4 cm. lower down. After the fibres of the Glutæus maximus have been separated, the vessel is to be sought at the lower border of the Piriformis; the sciatic nerve, which lies just above it, forms the chief guide to the artery.

The External Iliac Artery (fig. 703)

The **external iliac artery** is larger than the hypogastric artery, and runs obliquely downwards and lateralwards, along the medial border of the Psoas major, from the bifurcation of the common iliac artery to a point beneath the inguinal ligament, midway between the anterior superior iliac spine and the symphysis pubis, where it enters the thigh as the femoral artery.

Relations.—*In front and medially* the external iliac artery is in relation with the peritoneum and subperitoneal areolar tissue which separate the right artery from the termination of the ileum and frequently the vermiform process, and the left artery from the sigmoid colon and some coils of the small intestine. The beginning of the artery may be crossed by the ureter; in the female it is crossed by the ovarian vessels. The testicular vessels lie for some distance upon it near its termination, and it is crossed in this situation by the external spermatic branch of the genitofemoral nerve, the deep iliac circumflex vein, the ductus deferens in the male, and the round ligament of the uterus in the female. *Posteriorly*, it is separated from the medial border of the Psoas major by the iliac fascia. The external iliac vein lies partly behind the upper part of the artery, but is on the medial side of its lower part. *Lateral* to it is the Psoas major, from which it is separated by the iliac fascia. Numerous lymphatic vessels and lymph-glands lie on the front and sides of the vessel.

Applied Anatomy.—The external iliac artery may be ligatured in any part of its course, excepting near its upper end, which is to be avoided on account of the proximity of the hypogastric artery, and near its lower end, which should also be avoided on account of the proximity of its inferior epigastric and deep iliac circumflex branches. The operation may be performed by opening the abdomen and incising the peritoneum over the artery (*transperitoneal*); or by an incision in the iliac region, dividing all the structures down to the peritoneum, which is then separated unopened from the iliac fossa until the artery is reached (*retroperitoneal*).

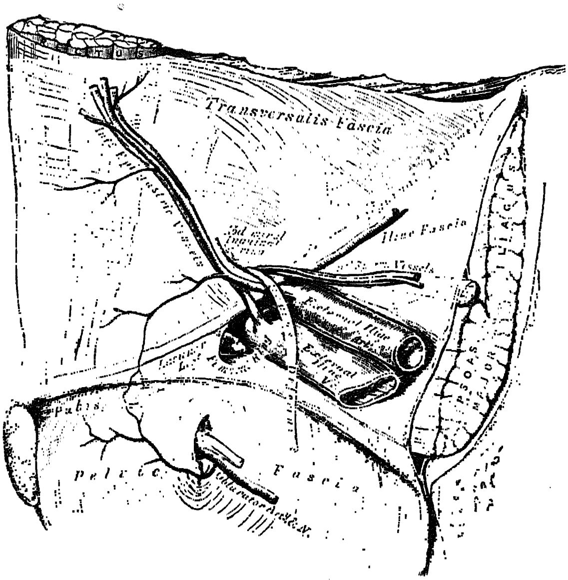
The transperitoneal ligature is essentially similar to that described on p. 678 for the common iliac artery. The advantages of this operation are: (1) if it be found necessary, the common iliac artery can be ligatured instead of the external iliac without extension or modification of the incision; and (2) the vessel can be ligatured without in any way interfering with the sac of an aneurysm.

The retroperitoneal ligature may be performed by an incision above and parallel to the lateral half of the inguinal ligament. The abdominal muscles and transversalis fascia having been divided, the peritoneum should be separated from the iliac fossa and raised towards the pelvis; and on introducing the finger to the bottom of the wound, the artery may be felt pulsating along the medial border of the Psoas major. The external iliac vein, generally found on the medial side of the artery, must be cautiously separated from it, and the aneurysm needle introduced on the medial side, between the artery and vein.

Collateral Circulation.—The principal anastomoses by which the collateral circulation is established, after ligature of the external iliac artery, are: the iliolumbar with the iliac circumflex arteries; the superior glutæal with the lateral femoral circumflex artery; the obturator with the medial femoral circumflex artery; the inferior glutæal with the circumflex and first perforating branches of the arteria profunda femoris; and the internal pudendal with the external pudendal artery. When the obturator artery arises from the inferior epigastric artery, it is supplied with blood by branches from either the hypogastric, the lateral sacral, or the internal pudendal arteries. The inferior epigastric artery receives its supply from the internal mammary and lower intercostal arteries, and from the hypogastric artery by the anastomoses of its branches with the obturator artery.*

Branches.—Besides supplying several small branches to the Psoas major and the neighbouring lymph-glands, the external iliac artery gives off the inferior epigastric and deep circumflex iliac branches.

Fig. 709.—The right inferior epigastric artery, and the relations of the right femoral and abdominal inguinal rings. Seen from within the abdomen.



The **inferior epigastric artery** (deep epigastric artery) (figs. 559, 709) arises from the external iliac artery, immediately above the inguinal ligament. It curves forwards in the subperitoneal tissue, and then ascends obliquely along the medial margin of the abdominal inguinal ring; continuing its upward course, it pierces the transversalis fascia, passes in front of the linea semicircularis, and ascends between the Rectus abdominis and the posterior lamella of its sheath. It finally divides into numerous branches, which anastomose, above the umbilicus, with the superior epigastric branch of the internal mammary artery and with the lower intercostal arteries. As the inferior epigastric artery passes obliquely upwards from its origin it lies along the lower and medial margins of the abdominal inguinal ring, and behind the commencement of the spermatic cord. In the male the ductus deferens, and in the female the round ligament of the uterus, winds round the lateral and posterior aspects of the artery. The inferior epigastric artery supplies the following branches:

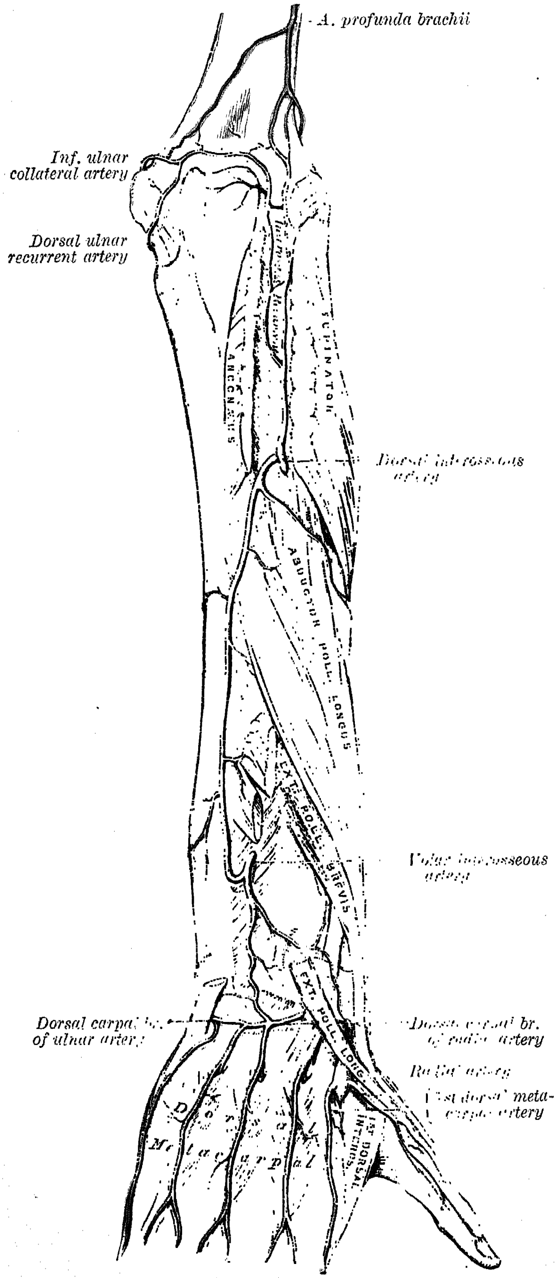
The **external spermatic artery** (cremasteric artery) accompanies the spermatic cord, supplies the Cremaster and other coverings of the cord, and anastomoses with the testicular artery. In the female the external spermatic artery is very small and accompanies the round ligament of the uterus.

A **pubic branch** descends along the medial margin of the femoral ring to the back of the os pubis, and there anastomoses with the pubic branch of the obturator artery. In

* Sir Astley Cooper describes in vol. i of the *Guy's Hospital Reports* the dissection of a limb eighteen years after successful ligature of the external iliac artery.

pollicis longus, and descends between the superficial and deep layers of muscles, to both of which it distributes branches. As it lies upon the Abductor pollicis longus, it is accompanied by the deep branch of the radial nerve. At the lower part of the forearm it anastomoses with the termination of the volar interosseous artery, and with the dorsal carpal network. It gives off, near its origin, the *interosseous recurrent artery*, which ascends to the interval between the lateral epicondyle and olecranon, on or through the fibres of the Supinator, but beneath the Anconæus, and anastomoses with the radial collateral branch of the arteria profunda brachii, the dorsal ulnar recurrent, and the inferior ulnar collateral arteries.

FIG. 693.—The arteries of the dorsal surface of the right forearm and hand.



The **muscular branches** are distributed to the muscles along the ulnar side of the forearm.

The **volar carpal branch** is a small vessel which crosses the front of the carpus behind the tendons of the Flexor digitorum profundus; it anastomoses with the volar carpal branch of the radial artery, and assists in forming the volar carpal network.

The **dorsal carpal branch** arises immediately above the pisiform bone, and winds backwards beneath the tendon of the Flexor carpi ulnaris; it passes across the dorsal surface of the carpus under cover of the extensor tendons, anastomoses with the dorsal carpal branch of the radial artery, and assists in forming the dorsal carpal network. Near to its origin it gives off a small branch, which runs along the ulnar side of the fifth metacarpal bone, and supplies the ulnar side of the dorsal surface of the little finger.

The **deep volar branch** (fig. 689) passes between the Abductor digiti quinti and Flexor digiti quinti brevis, and through the origin of the Opponens digiti quinti; it anastomoses with the radial artery, and completes the deep volar arch.

The **superficial volar arch** (superficial palmar arch) (fig. 686) is formed mainly by the ulnar artery, and is usually completed by a branch from the arteria volaris indicis radialis, but sometimes by the superficial volar artery or by a branch from the

Fig. 710.—The femoral sheath laid open to show its three compartments.

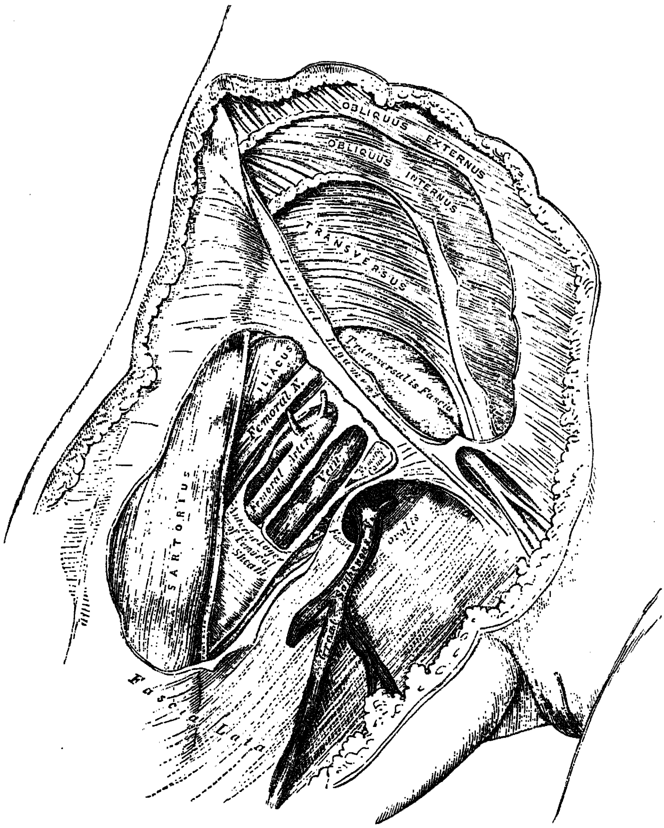
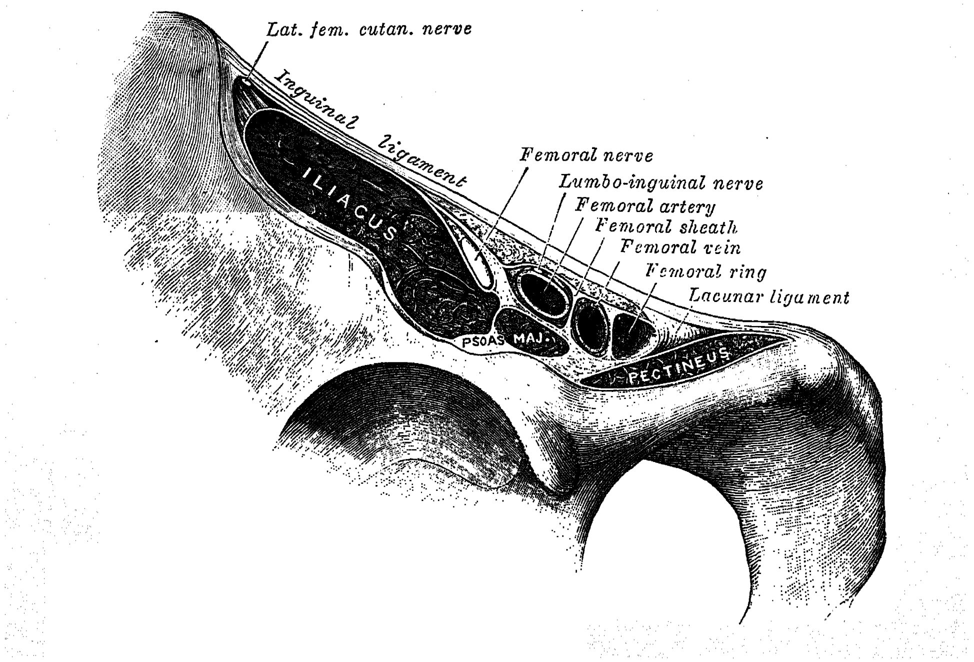
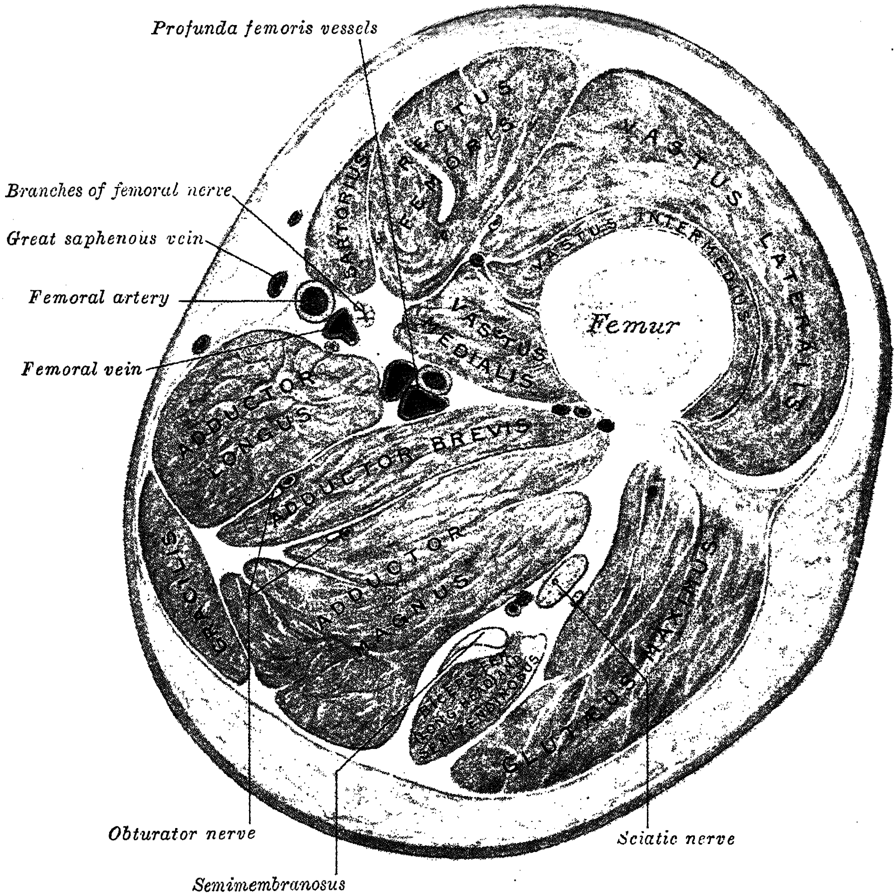


Fig. 711.—The structures passing behind the inguinal ligament.



stretch between its anterior and posterior walls. The lateral compartment contains the femoral artery, and the intermediate the femoral vein ; the medial and smallest compartment is named the *femoral canal*, and contains some lymphatic vessels and a lymph-gland, imbedded in a small amount of areolar tissue. The femoral canal is conical and measures 1·25 cm. in length ; its base, directed upwards and named the *femoral ring*, is oval in form, its long or transverse diameter measuring 1·25 cm. The femoral ring (fig. 711) is bounded in front by the inguinal ligament, behind by the Pectineus covered by its fascia, medially by the crescentic base of the lacunar ligament, and

Fig. 712.—A transverse section through the thigh at the level of the apex of the femoral triangle. Four-fifths of natural size.



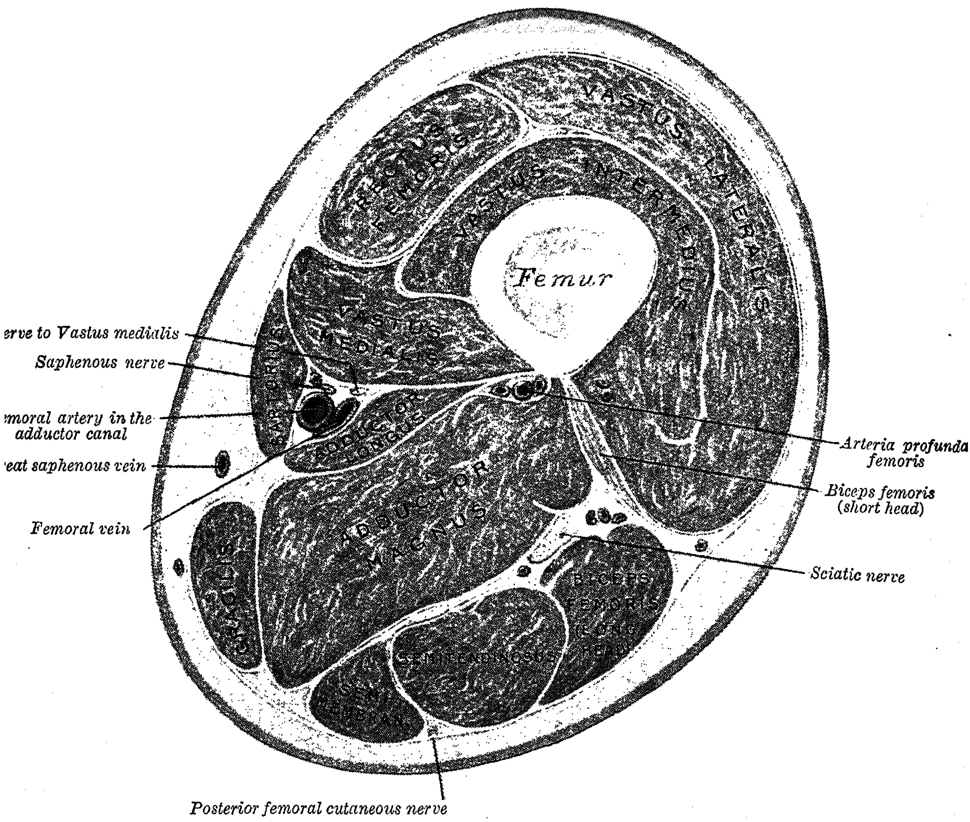
laterally by the femoral vein. The spermatic cord in the male, and the round ligament of the uterus in the female, lie immediately above the anterior margin of the ring, while the inferior epigastric vessels are close to its upper and lateral angle. The femoral ring is closed by a somewhat condensed portion of the extraperitoneal connective tissue, named the *septum femorale* (crural septum), the abdominal surface of which supports a small lymph-gland and is covered by the parietal layer of the peritoneum. The septum femorale is pierced by numerous lymphatic vessels passing from the deep inguinal to the external iliac lymph-glands, and the parietal peritoneum immediately above it presents a slight depression named the *femoral fossa*.

The **femoral triangle** (triangle of Scarpa) (fig. 714) corresponds to the depression seen immediately below the fold of the groin. Its apex is directed downwards, and the sides are formed, laterally by the medial margin of the Sartorius, medially by the medial margin of the Adductor longus, above by

the inguinal ligament. The floor of the triangle is formed from its lateral to its medial side by the Iliacus, Psoas major, Pectineus, and Adductor longus; and it is divided into two nearly equal parts by the femoral vessels, which extend from near the middle of its base to its apex. On the lateral side of the femoral artery is the femoral nerve dividing into its branches. Besides the vessels and nerves, this triangle contains some fat and lymphatics.

The **adductor canal** (Hunter's canal) (fig. 713) is an aponeurotic tunnel in the middle one-third of the thigh, extending from the apex of the femoral triangle to the opening in the Adductor magnus. It is triangular on transverse section, and is bounded, in front and laterally, by the Vastus medialis; behind,

FIG. 713.—A transverse section through the middle of the thigh. Four-fifths of natural size.



by the Adductor longus and Adductor magnus; and is roofed by a strong aponeurosis which extends from these muscles, across the femoral vessels, to the Vastus medialis; lying on the aponeurosis is the Sartorius. The canal contains the femoral artery and vein, the saphenous nerve; the nerve to the Vastus medialis traverses the proximal part of the abductor canal, and then enters its muscle.

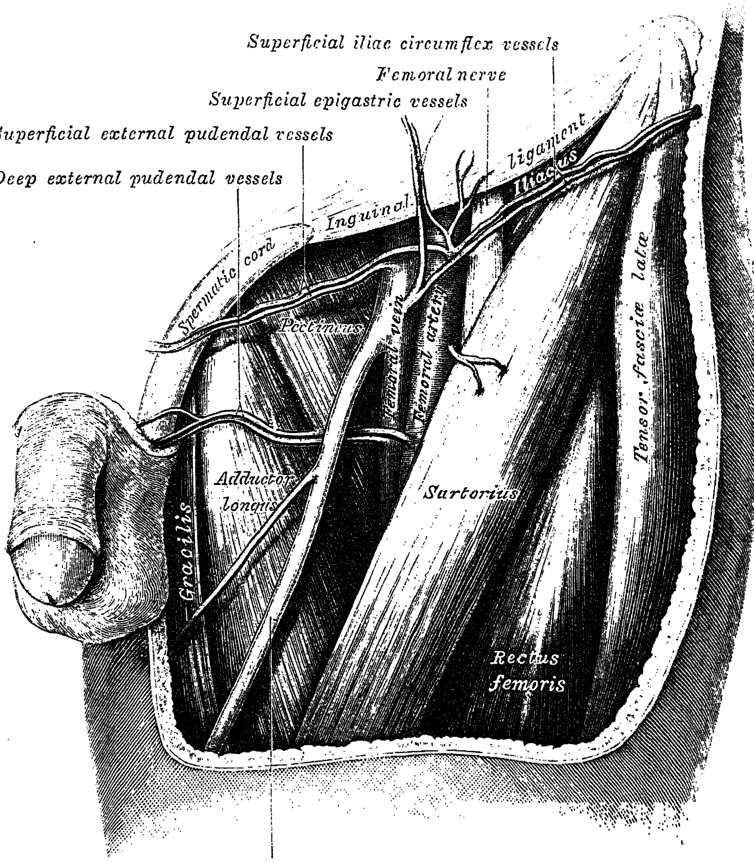
The **relations of the femoral artery.**—In the *femoral triangle* (fig. 714) the artery is covered by the skin and superficial fascia, the superficial subinguinal lymph-glands, the superficial iliac circumflex vein, the superficial layer of the fascia lata, and the anterior part of the femoral sheath. The lumbo-inguinal nerve courses for a short distance within the lateral compartment of the femoral sheath, and lies at first in front of and then lateral to the artery. Near the apex of the femoral triangle the medial branch of the anterior femoral cutaneous nerve crosses the artery from its lateral to its medial side.

Behind the artery are the posterior part of the femoral sheath, the pectineal fascia, the tendon of the Psoas major, the Pectineus and the Adductor longus.

The artery is separated from the capsule of the hip-joint by the tendon of the Psoas major, from the Pectineus by the femoral vein and profunda vessels, and from the Adductor longus by the femoral vein. The nerve to the Pectineus passes medialwards behind the artery. On the *lateral* side of the artery, is the femoral nerve. The femoral vein is medial to the artery in the upper part of the femoral triangle, and posterior to the artery in the lower part.

In the *adductor canal* (figs. 713, 716) the femoral artery is more deeply situated, being covered by the skin, the superficial and deep fasciæ, the Sartorius, and the

Fig. 714.—The left femoral triangle.



fibrous roof of the canal. The saphenous nerve is at first on the lateral side of the artery; it then lies in front of it, and below is placed on its medial side. Behind the artery are the Adductor longus and Adductor magnus; in front and lateral to it is the Vastus medialis. The femoral vein lies posterior to the upper, and lateral to the lower, part of the artery.

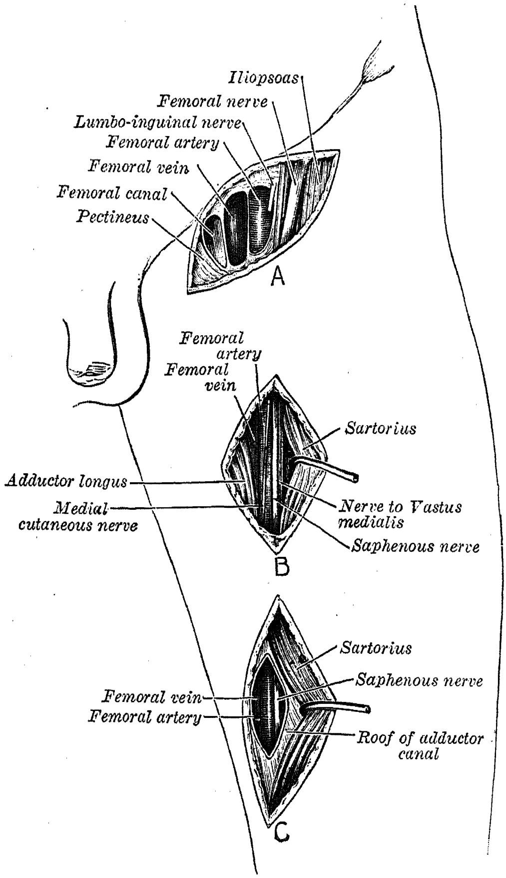
Peculiarities.—Several instances are recorded where the femoral artery divided, below the origin of the arteria profunda femoris, into two trunks, which reunited near the opening in the Adductor magnus; a few have been reported where the femoral artery was absent, its place being supplied by the inferior glutæal artery which accompanied the sciatic nerve to the popliteal fossa; in these the external iliac artery was small, and ended as the arteria profunda femoris. The femoral vein is occasionally placed along the medial side of the artery throughout the entire extent of the femoral triangle; or it may be duplicated so that a large vein is placed on either side of the artery for a greater or lesser distance.

Applied Anatomy.—Compression of the femoral artery, which is constantly requisite in amputations and other operations on the lower limb, is most effectually made immediately below the inguinal ligament. In this situation the artery is superficial, and is separated

from the superior ramus of the os pubis by the Psoas major ; here digital compression will effectually control the circulation through it. The vessel may also be controlled in the middle third of the thigh by a tourniquet, which presses the vessel against the medial side of the femur.

The femoral artery may be exposed and tied in any part of its course. The most favourable situation is at the apex of the femoral triangle (fig. 715, B). An incision 7 cm. long should be made in the course of the vessel, the patient lying in the recumbent position with the limb slightly flexed and abducted, and rotated outwards. A large vein is frequently met with, passing in the course of the artery to join the great saphenous vein, and must be avoided. The fascia lata having been cautiously divided, and the Sartorius displayed, that muscle must be drawn lateralwards in order to expose fully the sheath of the vessels. The finger having been introduced into the wound, and the pulsation of the artery felt, the sheath is opened on the lateral side of the vessel to a sufficient extent to allow of the introduction of the aneurysm needle. In this part of the operation the saphenous nerve and the nerve to the Vastus medialis, which are in close relation with the sheath, should be avoided. The aneurysm needle must be kept close to the artery, to avoid the femoral vein, which lies behind the vessel in this part of its course, and is very closely bound up with it.

FIG. 715.—Dissections to show the femoral artery (A) at the base of the femoral triangle, (B) at the apex of the femoral triangle, and (C) in the adductor (Hunter's) canal.



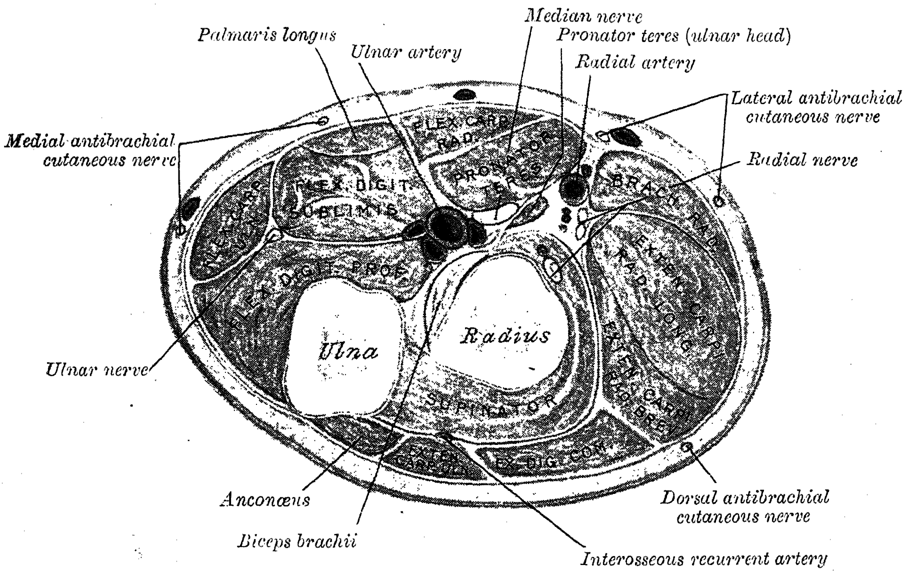
To ligature the artery immediately below the inguinal ligament (fig. 715, A) an incision 7 cm. in length is made with its centre a little below the ligament. The fascia lata is divided, and the sheath of the artery opened on the lateral side, where the lumbo-inguinal nerve may be met with. The aneurysm needle is now passed within the sheath from the medial to the lateral side of the artery so as to avoid injury to the femoral vein. The femoral nerve, lying on the lateral side of the artery, is separated from it by the femoral sheath and the fascia iliaca, and should not be seen (fig. 711).

To expose the artery in the adductor canal (fig. 715, C), an incision 7 cm. in length should be made a finger's breadth medial to the line of the artery, the centre of the incision being in the middle of the thigh—i.e. midway between the groin and the knee. The fascia lata having been divided, and the lateral border of the Sartorius exposed, this muscle should be drawn medialwards, when the strong fascia which is stretched across from the Adductors to the Vastus medialis will be observed, and must be freely divided ; the sheath of the vessels is now seen, and must be opened, and the artery secured by passing the aneurysm needle between it and the vein, from the lateral to the medial side of the artery. In this situation the femoral vein lies lateral to, and the saphenous nerve in front of the artery.

Collateral Circulation.—After ligature of the femoral artery, the main channels for carrying on the circulation are the following anastomoses :—(1) the superior and inferior glutæal branches of the hypogastric artery with the medial and lateral femoral circumflex and first perforating branches of the arteria profunda femoris ; (2) the obturator branch of the hypogastric artery with the medial femoral circumflex of the arteria profunda femoris ; (3) the internal pudendal branch of the hypogastric artery with the superficial and deep external pudendal branches of the femoral artery ; (4) the deep iliac circumflex branch of

successively upon the tendon of the Biceps brachii, the Supinator, the insertion of the Pronator teres, the radial origin of the Flexor digitorum sublimis, the Flexor pollicis longus, the Pronator quadratus, and the lower end of the radius. In the upper one-third of its course it is placed between the Brachioradialis and the Pronator teres; in the lower two-thirds, between the tendons of the Brachioradialis and Flexor carpi radialis. The superficial branch of the radial nerve is close to the lateral side of the middle one-third of the artery; and some filaments of the lateral antibrachial cutaneous nerve run along the lower part of the artery as it winds round the wrist. The artery is accompanied by a pair of venæ comitantes. The portion of the radial artery which lies in front of the lower end of the radius and on the lateral side of the tendon of the Flexor carpi radialis is used clinically for observations on the pulse.

FIG. 687.—A transverse section through the forearm at the level of the radial (bicipital) tuberosity.



(*b*) *At the wrist* (figs. 690, 691), the radial artery reaches the back of the carpus by passing between the radial collateral ligament of the wrist and the tendons of the Abductor pollicis longus and Extensor pollicis brevis. It then descends on the navicular and greater multangular bones, and before disappearing between the heads of the first Interosseus dorsalis is crossed by the tendon of the Extensor pollicis longus. In the interval between the two Extensores pollicis it is crossed by the origin of the cephalic vein, and by the digital rami of the superficial branch of the radial nerve, which go to the thumb and index finger.

(*c*) *In the hand* (fig. 689), the radial artery passes from the proximal end of the first interosseous space, between the heads of the first Interosseus dorsalis, transversely across the palm; it lies at first beneath the oblique part of the Adductor pollicis, then runs between the oblique and transverse parts, or through the transverse part, of that muscle, and, at the base of the fifth metacarpal bone, anastomoses with the deep volar branch from the ulnar artery, completing the *deep volar arch* (fig. 689).

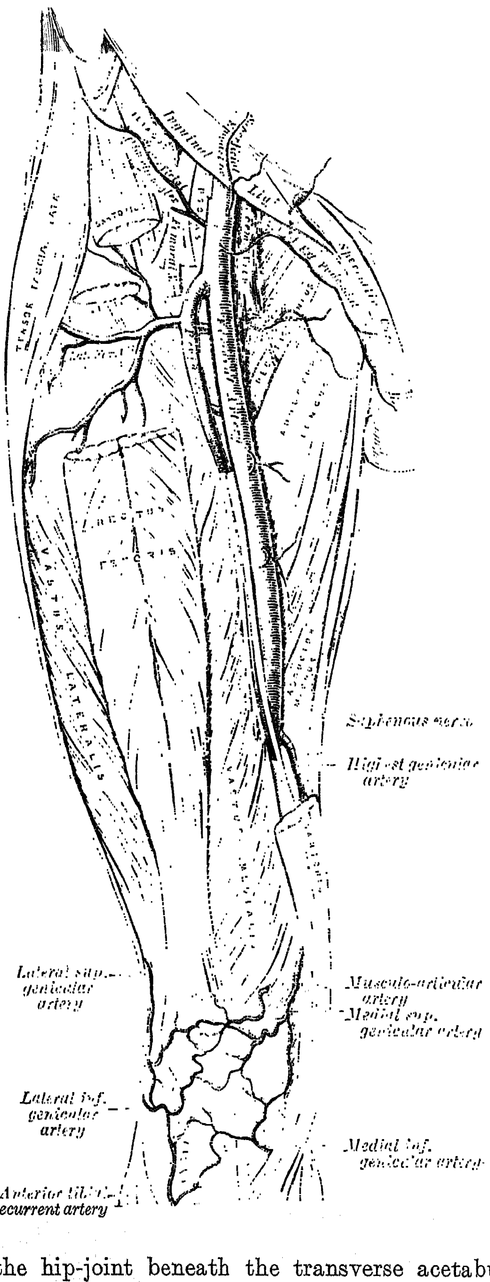
Peculiarities.—In about 12 per cent. of subjects the origin of the radial artery is higher than usual; it then arises more often from the axillary or upper part of the brachial artery than from the lower part of the latter vessel. In the forearm it sometimes lies on the deep fascia instead of beneath it, and on the surface of the Brachioradialis instead of under its medial border; in turning round the wrist, it occasionally lies on, instead of beneath, the extensor tendons of the thumb.

Applied Anatomy.—The radial artery is much exposed to injury in its lower one-third, and is frequently wounded; the injury may be followed by a traumatic aneurysm.

The *ascending branch* passes upwards beneath the Tensor fasciæ latæ to the lateral part of the hip, and anastomoses with the terminal branches of the superior glutæal and deep iliac circumflex arteries.

The *descending branch* runs downwards, behind the Rectus femoris, upon the Vastus lateralis, to which it gives offsets; one long branch descends in the latter muscle as far as the knee, and anastomoses with the superior lateral genicular branch of the popliteal artery. It is accompanied by the nerve to the Vastus lateralis.

FIG. 716.—The right femoral artery.



The *transverse branch*, the smallest, passes lateralwards over the Vastus intermedius, pierces the Vastus lateralis, and winds round the femur, just below the greater trochanter, anastomosing on the back of the thigh with the medial femoral circumflex, inferior glutæal, and first perforating arteries (*cruciate anastomosis*).

The **medial femoral circumflex artery** (internal circumflex artery) usually arises from the posteromedial aspect of the profunda artery, but frequently springs from the femoral artery. It winds round the medial side of the femur, passing first between the Pectineus and Psoas major, and then between the Obturator externus and Adductor brevis. At the upper border of the Adductor brevis it gives off two branches; one is distributed to the Adductores, the Gracilis, and Obturator externus, and anastomoses with the obturator artery; the other descends behind the Adductor brevis to supply it and the Adductor magnus; the continuation of the vessel passes backwards and divides into superficial, deep, and acetabular branches. The *superficial branch* appears between the Quadratus femoris and the upper border of the Adductor magnus, and takes part in the formation of the cruciate anastomosis. The *deep branch* runs obliquely upwards upon the tendon of the Obturator externus and in front of the Quadratus femoris towards the trochanteric fossa, where it anastomoses with twigs from the glutæal arteries. The *acetabular branch* arises opposite the acetabular notch and enters the hip-joint beneath the transverse acetabular ligament in company with an articular branch from the obturator artery; it supplies the fat in the bottom of the acetabulum, and is continued along the round ligament to the head of the femur.

The **perforating arteries** (fig. 708), usually three in number, are so named because they perforate the insertion of the Adductor magnus to reach the back of the thigh. They pass backwards close to the linea aspera of the femur under cover of small

tendinous arches in the insertion of the muscle. The first is given off above the Adductor brevis, the second in front of that muscle, and the third immediately below it.

The *first perforating artery* passes backwards between the Pectineus and Adductor brevis (sometimes it perforates the latter muscle); it then pierces the Adductor magnus close to the linea aspera. It gives branches to the Adductor brevis, Adductor magnus, Biceps femoris, and Glutæus maximus, and anastomoses with the inferior glutæal, medial and lateral femoral circumflex, and second perforating arteries.

The *second perforating artery*, larger than the first, but frequently arising in common with it, pierces the tendons of the Adductor brevis and Adductor magnus, and divides into ascending and descending branches which supply the posterior femoral muscles, anastomosing with the first and third perforating. The *nutrient artery* of the femur is usually given off from this artery; when two nutrient arteries exist, they usually spring from the first and third perforating vessels.

The *third perforating artery* is given off below the Adductor brevis; it pierces the Adductor magnus and divides into branches which supply the posterior femoral muscles, and anastomose above with the higher perforating arteries, and below with the termination of the profunda and the muscular branches of the popliteal. The nutrient artery of the femur may arise from this branch.

The termination of the profunda artery, already described, is sometimes called the *fourth perforating artery*.

The perforating arteries form a double chain of anastomosing vessels, (*a*) in the muscles and (*b*) close to the linea aspera.

Numerous **muscular branches** arise from the arteria profunda femoris; some of these end in the Adductores, others pierce the Adductor magnus, give branches to the hamstrings, and anastomose with the medial femoral circumflex artery and with the superior muscular branches of the popliteal artery.

7. The **highest genicular artery** (arteria anastomotica magna) (figs. 716, 720) arises from the femoral just before it passes through the opening in the tendon of the Adductor magnus, and immediately divides into a saphenous and a musculo-articular branch.

The *saphenous branch* pierces the lower part of the roof of the adductor canal, and accompanies the saphenous nerve to the medial side of the knee. It passes between the Sartorius and Gracilis, and is distributed to the skin of the upper and medial part of the leg, anastomosing with the medial inferior genicular artery.

The *musculo-articular branch* descends in the substance of the Vastus medialis, and in front of the tendon of the Adductor magnus, to the medial side of the knee, where it anastomoses with the medial superior genicular and anterior recurrent tibial arteries. An offset from the musculo-articular branch crosses above the patellar surface of the femur, forming an anastomotic arch with the lateral superior genicular artery, and supplying branches to the knee-joint.

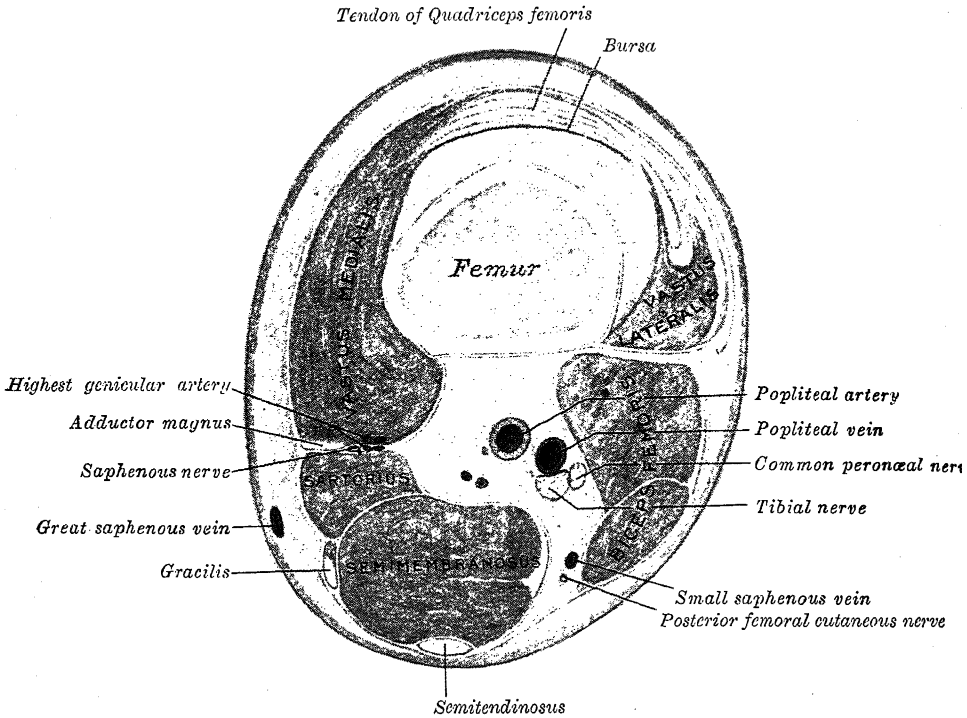
The Popliteal Fossa (figs. 717, 719)

Boundaries.—The **popliteal fossa or space** is a lozenge-shaped space at the back of the knee-joint. Laterally it is bounded by the Biceps femoris above, and by the Plantaris and the lateral head of the Gastrocnemius below; medially it is limited by the Semitendinosus and Semimembranosus above, and by the medial head of the Gastrocnemius below. The floor is formed by the popliteal surface of the femur, the oblique popliteal ligament of the knee-joint, the back of the upper end of the tibia, and the fascia covering the Popliteus; the fossa is covered by the popliteal fascia.

Contents (figs. 717, 719).—The popliteal fossa contains the popliteal vessels, the tibial and the common peronæal nerves, the termination of the small saphenous vein, the lower part of the posterior femoral cutaneous nerve, the articular branch from the obturator nerve, a few small lymph-glands, and a considerable quantity of fat. The tibial nerve descends through the middle of the fossa, lying under the popliteal fascia, and crossing the vessels posteriorly from the lateral to the medial side. The common peronæal nerve descends on the lateral side of the upper part of the fossa, close to the tendon of the Biceps femoris. On the floor of the fossa are the popliteal vessels, the vein being

superficial to the artery and united to it by dense areolar tissue; the vein is a thick-walled vessel, and lies lateral to the artery above, and then crosses it posteriorly to gain its medial side below; sometimes it is double, the artery lying between the two veins, which are usually connected by short transverse branches. The articular branch from the obturator nerve descends upon the artery to the knee-joint. The popliteal lymph-glands, six or seven in number,

FIG. 717.—A transverse section through the thigh, 4 cm. proximal to the adductor tubercle of the femur. Four-fifths of natural size.



are imbedded in the fat; one lies beneath the popliteal fascia near the termination of the external saphenous vein, another between the popliteal artery and the back of the knee-joint, while the others are placed at the sides of the popliteal vessels.

THE POPLITEAL ARTERY (figs. 717, 719)

The **popliteal artery** is the continuation of the femoral artery, and courses through the popliteal fossa. It extends from the opening in the Adductor magnus, at the junction of the middle with the lower one-third of the thigh, downwards and lateralwards to the intercondyloid fossa of the femur, and then vertically downwards to the lower border of the Popliteus, where it divides into *anterior* and *posterior tibial arteries.*

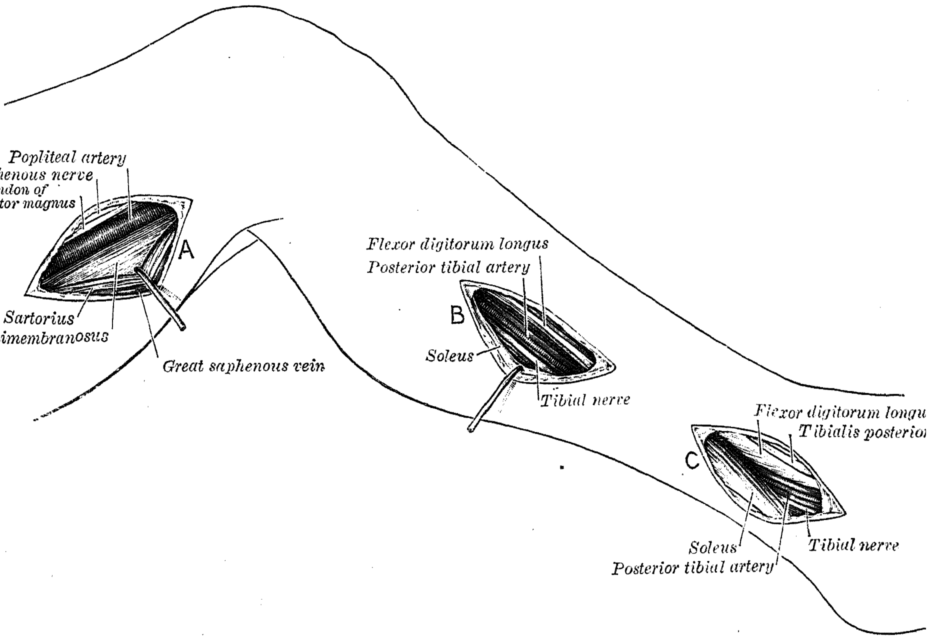
Relations.—In *front* of the artery, from above downwards, are the popliteal surface of the femur (separated from the vessel by some fat), the back of the knee-joint, and the fascia covering the Popliteus. *Behind*, it is overlapped by the Semimembranosus above, and is covered by the Gastrocnemius and Plantaris below. In the middle part of its course the artery is separated from the skin and fasciæ by a quantity of fat, and is crossed from the lateral to the medial side by the tibial nerve and the popliteal vein, the vein being between the nerve and the artery and closely adherent to the latter. On its *lateral side*, above, are the Biceps femoris, the tibial nerve, the popliteal vein, and the lateral condyle of the femur; below, the Plantaris and the lateral head of the Gastrocnemius. On its *medial* side, above, are the Semimembranosus and the medial condyle of the femur; below, the tibial

nerve, the popliteal vein, and the medial head of the Gastrocnemius. The relations of the popliteal lymph-glands to the artery are described on the previous page.

Peculiarities.—Occasionally the popliteal artery divides into its terminal branches opposite the knee-joint; when this occurs the anterior tibial artery usually descends in front of the Popliteus. The popliteal artery sometimes divides into the anterior tibial and peronæal arteries, the posterior tibial artery being wanting or rudimentary; occasionally it divides into three branches, the anterior and posterior tibial, and peronæal arteries.

Applied Anatomy.—The popliteal artery is not infrequently the seat of injury. It may be torn by direct violence, as by the passage of a cart-wheel over the knee, or by hyperextension of the knee. It may also be lacerated by fracture of the lower part of the femur, or by anteroposterior dislocation of the knee-joint. It has been torn in break-

FIG. 718.—Dissections to show (A) the popliteal artery, (B) the upper part of the posterior tibial artery, and (C) the lower part of the posterior tibial artery.

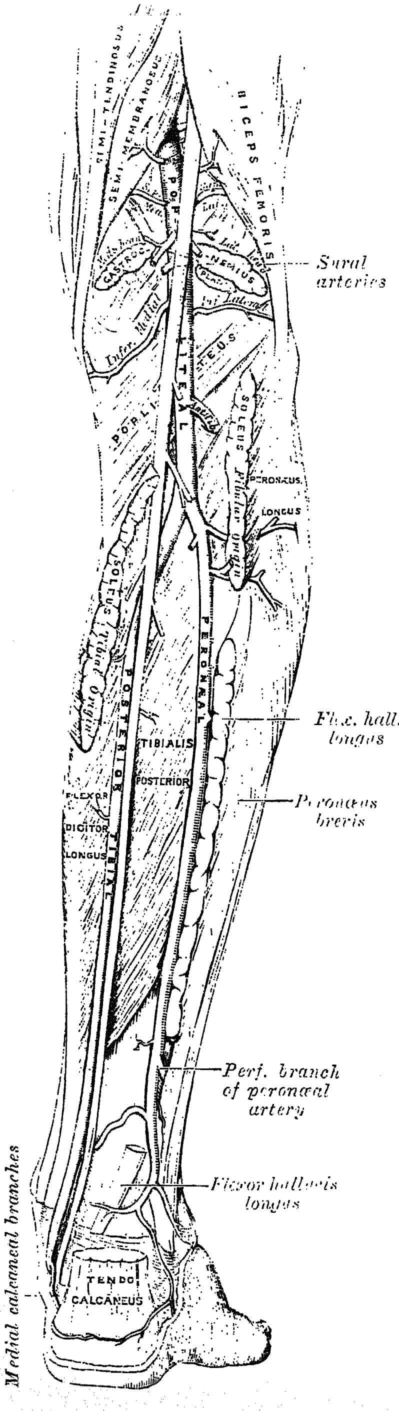


ing down adhesions in cases of fibrous ankylosis of the knee, and is in danger of being wounded in performing Macewen's operation of osteotomy of the lower end of the femur for genu valgum. It is more frequently the seat of aneurysm than any other artery except the thoracic aorta. No doubt this is due in a great measure to the amount of movement to which it is subjected, and to the fact that it is supported by loose and lax tissue only, and not by muscles, as is the case with most arteries. When the knee is acutely flexed, the popliteal artery becomes bent on itself to such an extent as entirely to arrest the circulation through it.

In order to expose the upper part of the vessel (fig. 718, A), the patient should be placed in the supine position, with the knee flexed and the thigh abducted and rotated outwards so that it rests on its lateral surface; an incision 7 cm. or 8 cm. in length, beginning at the junction of the middle with the lower one-third of the thigh, is to be made parallel to and immediately behind the tendon of the Adductor magnus, and the skin, superficial and deep fasciæ divided. The tendon of the muscle is thus exposed, and is to be drawn forwards, and that of the Sartorius backwards. A quantity of fatty tissue will now be opened up, in which the artery will be felt pulsating. This tissue is to be separated with the point of a director until the artery is exposed. The vein and nerve will not be seen, as they lie to the lateral side of the artery. The sheath is to be opened, and the aneurysm needle passed from before backwards, keeping its point close to the artery for fear of injuring the vein. The only structure to avoid in the superficial incision is the great saphenous vein.

To expose the vessel in the lower part of its course, where it lies between the two heads of the Gastrocnemius, the patient should be placed in the prone position with the limb extended. An incision should then be made through the skin in the middle line, commencing opposite the bend of the knee-joint, care being taken to avoid the small saphenous vein and the medial sural cutaneous nerve. After dividing the deep fascia, and separating some dense cellular tissue, the artery, vein, and nerve will be exposed between the two heads of the Gastrocnemius. Some muscular branches of the artery should be avoided if possible, or, if divided, tied immediately. The leg being now flexed, in order the more effectually to separate the two heads of the Gastrocnemius, the nerve should be drawn medialwards and the vein lateralwards, and the aneurysm needle passed between the artery and vein from the lateral to the medial side.

FIG. 719.—The right popliteal, posterior tibial, and peronæal arteries.



Branches.—The branches of the popliteal artery are:

Cutaneous.
Muscular { Superior. / Sural.
Genicular { Superior { medial. / lateral. / Middle / Inferior { medial. / lateral.

The **cutaneous branches** arise either from the popliteal artery or from some of its branches; they descend between the two heads of the Gastrocnemius, and, piercing the deep fascia, are distributed to the skin of the back of the leg; one usually accompanies the small saphenous vein.

The **superior muscular branches,** two or three in number, arise from the upper part of the artery, and pass to the Adductor magnus and the hamstring muscles, anastomosing with the terminal part of the arteria profunda femoris.

The **sural arteries** are two large branches which arise opposite the knee-joint and are distributed to the Gastrocnemius, Soleus, and Plantaris.

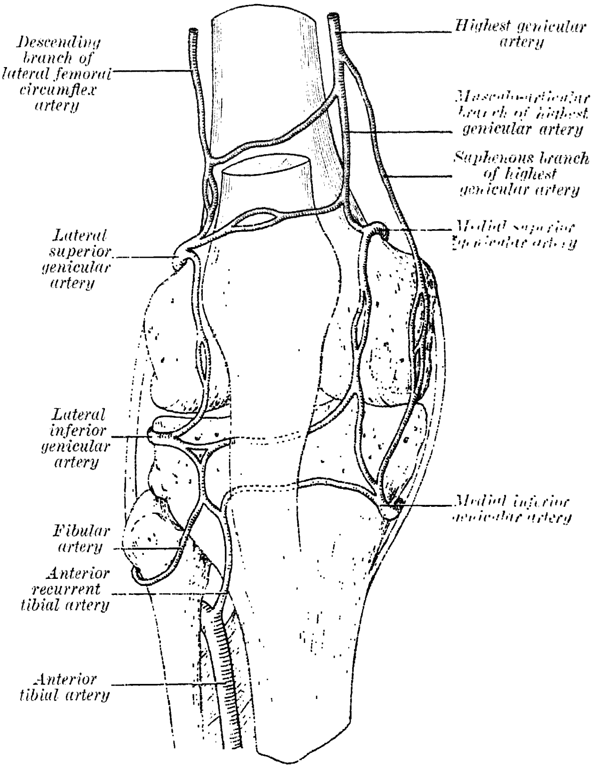
The **superior genicular arteries** (superior articular arteries) (figs. 719, 720), two in number, arise one on either side of the popliteal artery, and wind round the femur immediately above its condyles to the front of the knee-joint. The *medial superior genicular artery* runs in front of the Semimembranosus and Semitendinosus, above the medial head of the Gastrocnemius, and passes beneath the tendon of the Adductor magnus. It divides into two branches, one of which supplies the Vastus medialis and anastomoses with the highest genicular and medial inferior genicular arteries; the other ramifies close to the surface of the femur, and anastomoses with the lateral superior genicular artery. The

size of the medial superior genicular artery varies inversely with that of the highest genicular. The *lateral superior genicular artery* passes beneath the tendon of the Biceps femoris, and divides into a superficial and a deep branch; the superficial branch supplies the Vastus lateralis, and anastomoses with the descending branch of the lateral femoral circumflex artery and with the lateral inferior genicular artery; the deep branch anastomoses with the medial superior genicular artery, and forms an arch across the front of the bone with the highest genicular artery.

The **middle genicular artery** (azygos articular artery), a small branch, arises from the popliteal artery opposite the back of the knee-joint; it pierces the oblique popliteal ligament, and supplies the cruciate ligaments and the synovial stratum of the articular capsule.

The **inferior genicular arteries** (inferior articular arteries) (figs. 719, 720), two in number, arise from the popliteal artery beneath the Gastrocnemius. The *medial inferior genicular artery* descends along the upper margin of the Popliteus, to which it gives branches; it then passes below the medial condyle of the tibia and beneath the tibial collateral ligament; at the anterior border of this ligament it ascends to the front and medial side of the joint, supplies the joint and the upper end of the tibia, and anastomoses with the lateral inferior and medial superior genicular arteries. The *lateral inferior genicular artery* runs lateralwards across the Popliteus, and then forwards above the head of the fibula to the front of the knee-joint, passing in its course beneath the lateral head of the Gastrocnemius, the fibular collateral ligament, and the tendon of the Biceps femoris. It divides into branches which anastomose with the medial inferior genicular, lateral superior genicular, and anterior recurrent tibial arteries.

FIG. 720.—The arterial anastomosis around the knee-joint.

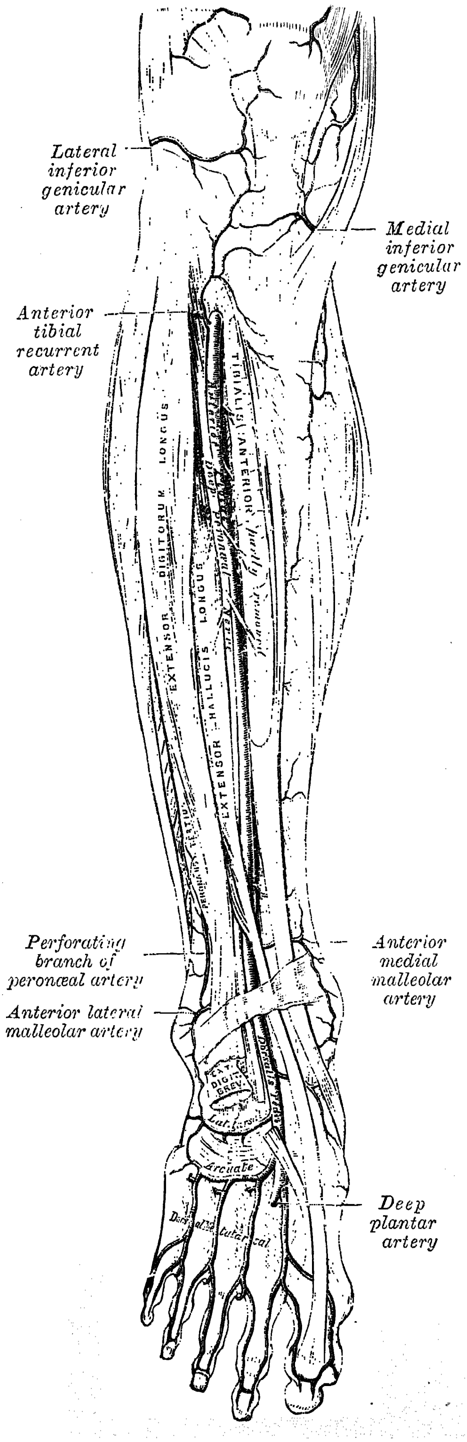


The **anastomosis around the knee-joint** (fig. 720).—Around and above the patella, and on the contiguous ends of the femur and tibia, an intricate arterial anastomosis forms a superficial and a deep network. The *superficial network* is situated between the fascia and skin round about the patella, and forms three well-defined arches; one above the patella in the loose connective tissue over the Quadriceps femoris, and two below the patella in the fat behind the ligamentum patellæ. The *deep network* lies on the lower end of the femur and upper end of the tibia around their articular surfaces, and sends numerous offsets into the interior of the joint. The arteries which form the anastomosis are the two medial and the two lateral genicular branches of the popliteal, the highest genicular, the descending branch of the lateral femoral circumflex, the fibular, and the anterior recurrent tibial.

The Anterior Tibial Artery (figs. 721, 723)

The **anterior tibial artery** begins at the bifurcation of the popliteal artery, at the lower border of the Popliteus. It passes forwards between the two heads of the Tibialis posterior and through the upper part of the crural interosseous membrane, to the front of the leg, lying close to the medial side of the neck of the fibula. It now descends on the anterior surface of the crural interosseous membrane, gradually approaching the tibia: at the lower part of the leg it lies on this bone (fig. 724), and then on the front of the ankle-joint midway between the two malleoli, and is continued on to the dorsum of the foot under the name of the *dorsalis pedis* artery.

Fig. 721.—The right anterior tibial and dorsalis pedis arteries.



Relations.—In the upper two-thirds of its extent, the anterior tibial artery rests upon the crural interosseous membrane; in the lower one-third, upon the front of the tibia and the ankle-joint. In the upper one-third of its course, it lies between the Tibialis anterior and Extensor digitorum longus; in the middle one-third between the Tibialis anterior and Extensor hallucis longus. At the ankle it is crossed from the lateral to the medial side by the tendon of the Extensor hallucis longus, and then lies between it and the first tendon of the Extensor digitorum longus. Its upper two-thirds are covered by the muscles which lie on either side of it, and by the deep fascia; its lower one-third, by the skin and fascia, and the transverse and cruciate crural ligaments.

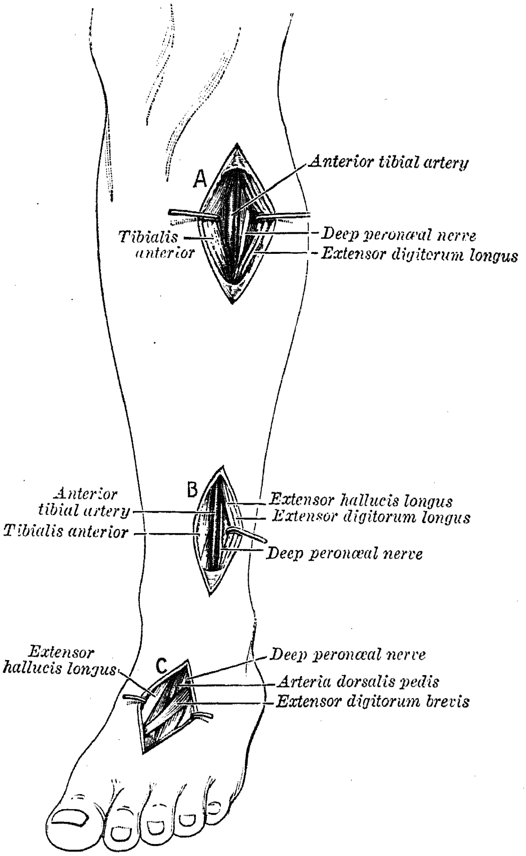
A pair of venæ comitantes lie one on either side of the artery. The deep peronæal nerve, coursing round the lateral side of the neck of the fibula, comes into relation with the lateral side of the artery shortly after it reaches the front of the leg; about the middle of the leg the nerve is in front of the artery; at the lower part it is generally on the lateral side again.

Peculiarities.—This vessel may be smaller than usual, or may be absent, its place being supplied by perforating branches from the posterior tibial, or by the perforating branch of the peronæal artery. The artery occasionally deviates towards the fibular side of the leg, regaining its usual position at the front of the ankle. Very occasionally it approaches the surface at the middle of the leg, and is covered merely by the skin and fascia below that point

Applied Anatomy.—The anterior tibial artery is liable to be injured in fractures of the lower third of the tibia, on account of its close proximity to the bone. Ligature of the anterior tibial artery in the upper half of the leg is difficult on account of the depth of the vessel from the surface (fig. 722, A). An incision about 10 cm. in length is made 3 cm. lateral to the anterior border of the tibia. The skin and superficial structures having been divided and the deep fascia exposed, the white line separating the Tibialis anterior from the Extensor digitorum longus is sought. When this has been clearly defined, the deep fascia is to be divided in this line, and the Tibialis anterior separated from adjacent muscles until the interosseous membrane is reached. The foot is to be flexed in order to relax the muscles, and upon drawing them apart the artery will be found lying on the interosseous membrane with the nerve lateral or superficial to it. The nerve should be drawn lateralwards, the venæ comitantes separated from the artery and the needle passed around it.

To tie the vessel in the lower one-third of the leg (fig. 722, B), an incision about 7 cm. in length should be made through the skin between the tendons of the Tibialis anterior and Extensor hallucis longus, the deep fascia being divided to the same extent. The tendon on either side should be retracted, when the vessel, accompanied by the venæ comitantes, will be seen lying upon the tibia, with the nerve on the lateral side.

FIG. 722.—Dissections to show (A) the upper, (B) the lower, part of the anterior tibial artery, and (C) the arteria dorsalis pedis.



Branches.—The branches of the anterior tibial artery are :

Posterior tibial recurrent.	Anterior medial malleolar.
Anterior tibial recurrent.	Anterior lateral malleolar.
Muscular.	

The **posterior tibial recurrent artery,** an inconstant branch, is given off from the anterior tibial artery before that vessel reaches the front of the leg. It ascends in front of the Popliteus in company with the nerve to that muscle, anastomoses with the inferior genicular branches of the popliteal artery, and gives an offset to the tibiofibular joint.

The **anterior tibial recurrent artery** (fig. 721) arises from the anterior tibial artery, as soon as that vessel has reached the front of the limb ; it ascends in the Tibialis anterior, ramifies on the front and sides of the knee-joint, and assists in the formation of the patellar network by anastomosing with the genicular branches of the popliteal artery, and with the highest genicular artery.

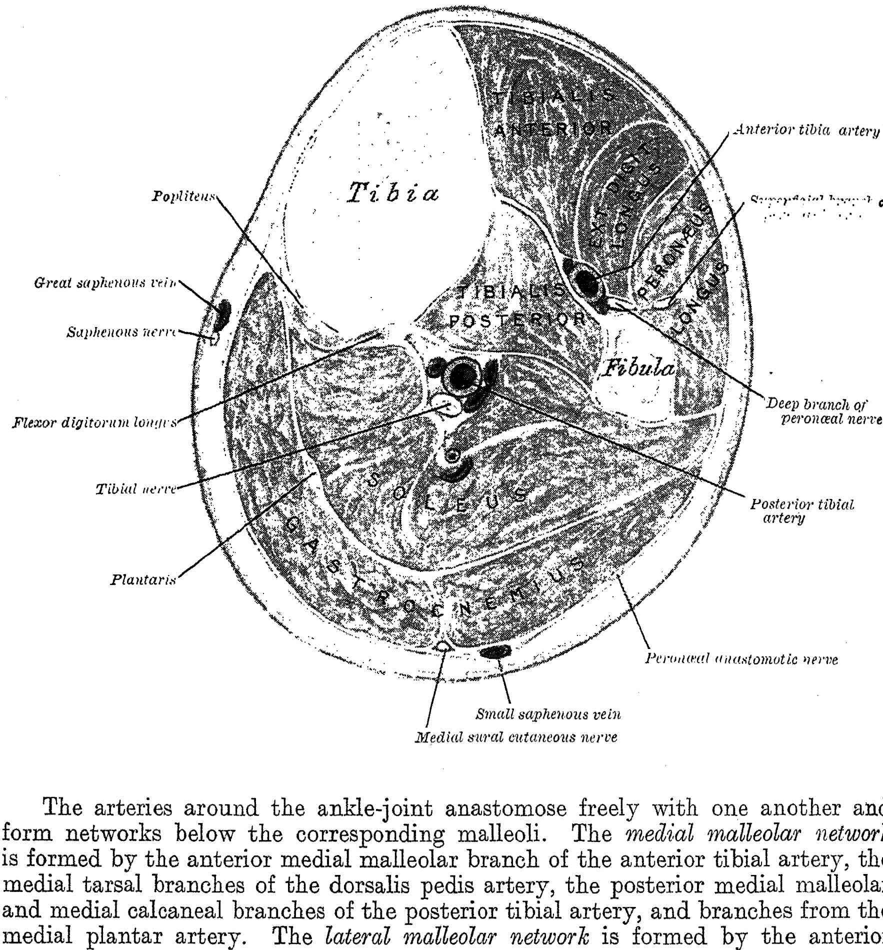
The **muscular branches** are numerous and are distributed to the muscles which lie on either side of the vessel ; some pierce the deep fascia to supply the skin, others pass through the crural interosseous membrane, and anastomose with branches of the posterior tibial and peronæal arteries.

The **anterior medial malleolar artery** (internal malleolar artery) (fig. 721) arises about 5 cm. above the ankle-joint, and passes behind the tendons of the Extensor

hallucis longus and Tibialis anterior, to the medial side of the ankle, where it anastomoses with branches of the posterior tibial and medial plantar arteries.

The **anterior lateral malleolar artery** (external malleolar artery) (fig. 721) passes beneath the tendons of the Extensor digitorum longus and Peronæus tertius; it supplies the lateral side of the ankle and anastomoses with the perforating branch of the peronæal artery and with ascending twigs from the lateral tarsal artery.

Fig. 723.—A transverse section through the leg, 9 cm. distal to the knee-joint.



The arteries around the ankle-joint anastomose freely with one another and form networks below the corresponding malleoli. The *medial malleolar network* is formed by the anterior medial malleolar branch of the anterior tibial artery, the medial tarsal branches of the dorsalis pedis artery, the posterior medial malleolar and medial calcaneal branches of the posterior tibial artery, and branches from the medial plantar artery. The *lateral malleolar network* is formed by the anterior lateral malleolar branch of the anterior tibial artery, the lateral tarsal branch of the dorsalis pedis artery, the perforating and the lateral calcaneal branches of the peronæal artery, and twigs from the lateral plantar artery.

The Arteria Dorsalis Pedis (fig. 721)

The **arteria dorsalis pedis**, the continuation of the anterior tibial artery, passes forwards from the ankle-joint along the tibial side of the dorsum of the foot to the proximal part of the first intermetatarsal space, where it divides into the *first dorsal metatarsal* and the *deep plantar arteries*.

Relations.—The arteria dorsalis pedis is accompanied by two veins, and lies successively upon the front of the articular capsule of the ankle-joint, the talus, navicular, and second cuneiform bones, and the ligaments connecting them. It is covered by the skin, fascia, and cruciate crural ligament, and crossed near its termination by the first tendon of the Extensor digitorum brevis. On its *tibial side* is the tendon of the Extensor hallucis longus; on its *fibular side*, the first tendon

of the Extensor digitorum longus, and the medial terminal branch of the deep peronæal nerve.

Peculiarities.—The arteria dorsalis pedis may be larger than usual, to compensate for a deficient plantar artery; or its place may be taken by a large perforating branch of the peronæal artery. It frequently curves lateralwards, lying lateral to the line between the middle of the ankle and the proximal part of the first interosseous space.

Applied Anatomy.—The arteria dorsalis pedis may be tied, by making an incision 5 cm. in length, through the skin on the fibular side of the tendon of the Extensor hallucis longus, in the interval between it and the medial border of the Extensor digitorum brevis (fig. 722, c). The incision should not extend farther forwards than the proximal part of the first intermetatarsal space, as the artery divides in that situation. When the deep fascia has been divided the artery will be exposed, with the deep peronæal nerve lying lateral to it.

Branches.—The branches of the arteria dorsalis pedis are:

Lateral tarsal.
Medial tarsal.
Arcuate.
First dorsal metatarsal.
Deep plantar.

The **lateral tarsal artery** (fig. 721) arises from the arteria dorsalis pedis as the latter crosses the navicular bone, and passes lateralwards beneath the Extensor digitorum brevis; it supplies this muscle and the articulations of the tarsus, and anastomoses with branches of the arcuate, anterior lateral malleolar, and lateral plantar arteries, and with the perforating branch of the peronæal artery.

The **medial tarsal arteries** are two or three small branches; they ramify on the medial border of the foot and join the medial malleolar network.

The **arcuate artery** (metatarsal artery) (fig. 721) arises from the arteria dorsalis pedis opposite the first cuneiform bone; it passes lateralwards over the bases of the metatarsal bones beneath the tendons of the Extensores digitorum longus et brevis, and anastomoses with the lateral tarsal and lateral plantar arteries. It gives off the *second, third,* and *fourth dorsal metatarsal arteries*, which run forwards upon the corresponding Interossei dorsales; in the clefts between the toes each divides into two dorsal digital branches for the sides of the adjoining toes. At the proximal parts of the interosseous spaces the dorsal metatarsal arteries receive the posterior perforating branches from the plantar arch, and at the distal parts of the spaces they are joined by the anterior perforating branches from the plantar metatarsal arteries. The fourth dorsal metatarsal artery gives off a branch which supplies the lateral side of the fifth toe.

The **first dorsal metatarsal artery** (arteria dorsalis hallucis) runs forward on the first Interosseus dorsalis, and at the cleft between the first and second toes divides into two branches, one of which passes beneath the tendon of the Extensor hallucis longus, and is distributed to the medial border of the great toe; the other bifurcates to supply the adjoining sides of the great and second toes.

The **deep plantar artery** (communicating artery) descends into the sole of the foot, between the two heads of the first Interosseus dorsalis, and completes the plantar arch by uniting with the lateral plantar artery. At its junction with this artery it gives off the *first plantar metatarsal artery* (p. 707).

The Posterior Tibial Artery (figs. 719, 723 724)

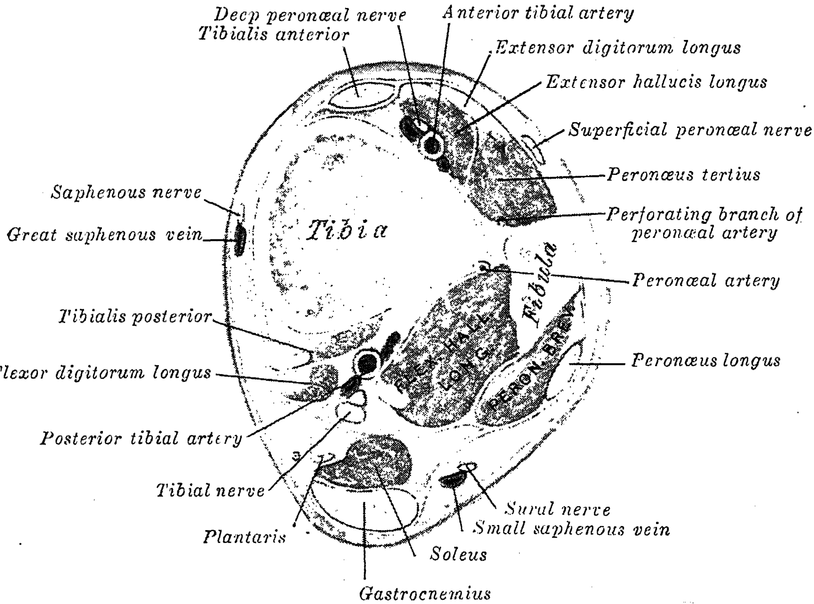
The **posterior tibial artery** begins at the lower border of the Popliteus, opposite the interval between the tibia and fibula, and passes downwards and medialwards on the back of the leg. In the lower part of its course it is situated midway between the medial malleolus and the medial process of the calcaneal tuberosity. It divides beneath the origin of the Abductor hallucis into the *medial and lateral plantar arteries*.

Relations.—The posterior tibial artery lies successively upon the Tibialis posterior, the Flexor digitorum longus, the tibia, and the back of the ankle-joint. Its upper part is beneath the Gastrocnemius and Soleus, and the deep transverse fascia of the leg; in the lower one-third of the leg it is covered only by the skin and fascia, and runs parallel with, and about 2·5 cm. in front of, the medial border of the tendo calcaneus; its terminal part is covered by the laciniate ligament and the Abductor hallucis. It is accompanied by two veins, and by the tibial nerve

which lies at first to its medial side, but soon crosses it posteriorly, and is, in the greater part of its course, on its lateral side.

The structures which pass from the back of the leg to the sole of the foot under cover of the laciniate ligament are arranged in the following order from the medial to the lateral side; first, the tendons of the Tibialis posterior and Flexor digitorum longus lying in the same groove behind the malleolus, the former being the more medial; then the posterior tibial artery, with a vein on either side of it; lateral to the posterior tibial vessels is the tibial nerve; and about 1·25 cm. nearer the heel is the tendon of the Flexor hallucis longus.

FIG. 724.—A transverse section through the leg, 6 cm. proximal to the tip of the medial malleolus.



Peculiarities.—The posterior tibial artery may be small or absent, its place being supplied by a large peronæal artery, which either joins the small posterior tibial artery, or continues alone to the sole of the foot.

Applied Anatomy.—Ligature of the posterior tibial artery may be required in cases of wound of the sole of the foot, attended with great hæmorrhage; the vessel should then be tied at the ankle. In cases of wound of the posterior tibial, it will be necessary to enlarge the opening so as to expose the vessel at the wounded point, excepting where the vessel is injured by a punctured wound from the front of the leg.

To tie the posterior tibial artery at the ankle, a curved incision, about 6 cm. long, and with its convexity directed backwards, should be made through the skin about one finger's breadth behind the medial malleolus. The subcutaneous tissue having been divided, the laciniate (internal annular) ligament is seen. This is divided, and the sheath of the vessels exposed and opened, when the artery is seen with one of the venæ comitantes on either side. The aneurysm needle should be passed round the vessel from the heel towards the ankle, in order to avoid the tibial nerve.

Ligature of the vessel in the middle of the leg (fig. 718, B) is a difficult operation, on account of its depth from the surface. The patient being placed in the recumbent position, the limb should rest on its fibular side, the knee being partially bent, and the foot extended, to relax the muscles of the calf. An incision about 10 cm. long should be made through the skin, a finger's breadth behind the medial margin of the tibia, care being taken to avoid the great saphenous vein. The deep fascia having been divided, the margin of the Gastrocnemius is exposed, and drawn aside, and the tibial attachment of the Soleus divided. The artery may now be felt pulsating beneath the deep transverse fascia, 2·5 cm. from the medial margin of the tibia. This fascia having been divided, and the limb placed in such a position as will relax the muscles of the calf as much as possible, the veins should be separated from the artery and the aneurysm needle passed round the vessel from the lateral to the medial side, so as to avoid the tibial nerve.

The vessel may be tied in the lower one-third of the leg by making an incision about 8 cm. long, parallel with the medial border of the tendo calcaneus (fig. 718, c). The great saphenous vein must be avoided, and the two layers of fascia divided upon a director, when the artery will be exposed along the lateral margin of the Flexor digitorum longus, with one of its venæ comitantes on either side, and the nerve lying lateral to it.

Branches.—The branches of the posterior tibial artery are :

1. Fibular.
2. Peronæal.
3. Nutrient.
4. Muscular.
5. Communicating.
6. Posterior medial malleolar.
7. Medial calcaneal.
8. Medial plantar.
9. Lateral plantar.

1. The **fibular artery,** sometimes a branch of the anterior tibial artery, passes lateralwards round the neck of the fibula, through the Soleus, and anastomoses with the lateral inferior genicular artery.

2. The **peronæal artery** (fig. 719) arises from the posterior tibial, about 2·5 cm. below the lower border of the Popliteus. It passes obliquely towards the fibula, and descends along the medial side of that bone, contained in a fibrous canal between the Tibialis posterior and the Flexor hallucis longus, or in the substance of the latter muscle. It then runs behind the inferior tibiofibular joint, and divides into lateral calcaneal branches which ramify on the lateral and posterior surfaces of the calcaneus. Its *upper* part is covered by the Soleus and the deep transverse fascia of the leg ; its *lower* part, by the Flexor hallucis longus.

Peculiarities.—The peronæal artery may spring from the posterior tibial artery at a higher level than usual, or may even be a branch of the popliteal artery ; sometimes it arises 7 or 8 cm. below the inferior border of the Popliteus. It is more frequently increased than diminished in size ; and then it either joins and reinforces the posterior tibial artery, or takes the place of that artery in the lower part of the leg and foot. When the peronæal artery is smaller than usual, a branch from the posterior tibial artery supplies its place ; and a branch from the anterior tibial artery compensates for the diminished perforating artery.

The peronæal artery gives off the following branches :

Muscular branches are supplied to the Soleus, Tibialis posterior, Flexor hallucis longus, and Peronæi.

A **nutrient artery** supplies the fibula, and is directed downwards.

A **perforating branch** pierces the crural interosseus membrane, about 5 cm. above the lateral malleolus, and reaches the front of the leg, where it anastomoses with the anterior lateral malleolar artery ; it then descends in front of the inferior tibiofibular joint, gives branches to the tarsus, and anastomoses with the lateral tarsal artery. The perforating branch is sometimes enlarged, and may take the place of the dorsalis pedis artery.

A **communicating branch** arises from the peronæal artery about 5 cm. above the lower end of the tibia, and joins the communicating branch of the posterior tibial artery.

Lateral calcaneal or terminal branches of the peronæal artery pass to the lateral side of the heel, and communicate with the anterior lateral malleolar artery and, on the back of the heel, with the medial calcaneal arteries.

3. The **nutrient artery** of the tibia arises from the posterior tibial artery near its origin, and, after supplying a few minute muscular branches, enters the nutrient canal in the bone, at a point immediately below the popliteal line ; the canal is directed downwards.

4. **Muscular branches** are distributed to the Soleus and to the deep muscles on the back of the leg.

5. The **communicating branch** runs transversely across the back of the tibia about 5 cm. above its lower end, beneath the Flexor hallucis longus, and joins the communicating branch of the peronæal artery.

6. The **posterior medial malleolar artery** is a small branch which winds round the tibial malleolus and ends in the medial malleolar network.

7. The **medial calcaneal branches** are several large arteries which arise from the posterior tibial just before its division ; they pierce the laciniate ligament and are distributed to the fat and skin behind the tendo calcaneus and about the heel, and to the muscles on the tibial side of the sole, anastomosing with the peronæal and medial malleolar arteries, and, on the back of the heel, with the lateral calcaneal arteries.

8. The **medial plantar artery** (internal plantar artery) (figs. 725, 726), the smaller terminal branch of the posterior tibial artery, passes forwards along the medial side of the foot. It passes deep to the Abductor hallucis, and then runs forwards between it and the Flexor digitorum brevis, both of which it supplies. At the base of the first metatarsal bone, where it is much diminished in size, it passes along the medial border of the first toe and anastomoses with the first dorsal metatarsal artery. It supplies three small superficial digital branches which accompany the digital branches of the medial plantar nerve and join the first, second and third plantar metatarsal arteries.

9. The **lateral plantar artery** (external plantar artery) (fig. 726), the larger of the terminal branches of the posterior tibial artery, passes at first obliquely lateralwards and forwards to the base of the fifth metatarsal bone in company with the lateral plantar nerve. It then turns medialwards with the deep branch of the nerve, to

Fig. 725.—The plantar arteries. Superficial dissection.

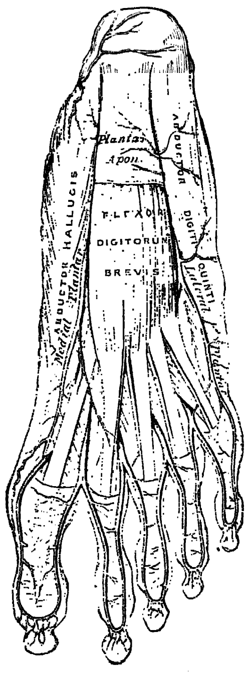
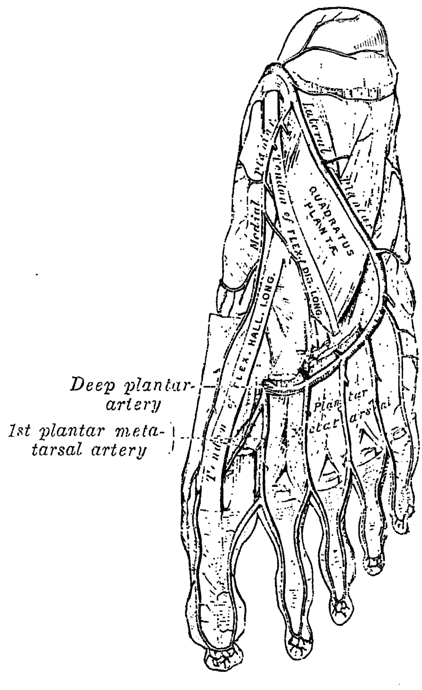


Fig. 726.—The plantar arteries. Deep dissection.



the interval between the bases of the first and second metatarsal bones, where it unites with the deep plantar branch of the dorsalis pedis artery, thus completing the *plantar arch.* As this artery passes lateralwards, it is first placed between the calcaneus and Abductor hallucis, and then between the Flexor digitorum brevis and Quadratus plantæ ; as it runs forwards to the base of the fifth metatarsal bone it lies between the Flexor digitorum brevis and Abductor digiti quinti, and is covered by the plantar aponeurosis, superficial fascia and skin. The remainder of the vessel is deeply situated ; it extends from the base of the fifth metatarsal bone to the proximal part of the first interosseous space, and forms the plantar arch ; it is convex forwards, lies below the bases of the second, third, and fourth metatarsal bones and the corresponding Interossei and upon the oblique part of the Adductor hallucis.

Branches.—The plantar arch gives off three perforating, and four plantar metatarsal, branches, and distributes numerous twigs to the skin, fasciæ and muscles in the sole.

The three **perforating branches** ascend through the proximal parts of the second, third, and fourth interosseous spaces, between the heads of the Interossei dorsales, and anastomose with the dorsal metatarsal arteries.

The four **plantar metatarsal arteries** (fig. 726) run forwards between the metatarsal bones and in contact with the Interossei. Each divides into a pair of plantar digital arteries which supply the adjacent sides of the toes. Near their points of division each plantar metatarsal artery sends upwards an *anterior perforating branch* to join the corresponding dorsal metatarsal artery. The first plantar metatarsal artery (arteria magna hallucis) springs from the junction between the lateral and deep plantar arteries (p. 703), and sends a digital branch to the medial side of the first toe. The digital branch for the lateral side of the fifth toe arises from the lateral plantar artery near the base of the fifth metatarsal bone.

Applied Anatomy.—Wounds of the plantar arch are always serious, on account of the depth of the vessel and the important structures which must be interfered with in an attempt to ligature it. They must be treated on similar lines to those of wounds of the volar arches (p. 661). Pressure locally, combined with elevation of the limb, may in some cases be sufficient to arrest the bleeding, but if this fails, an attempt should be made to find the bleeding point and ligature it. Should this prove unsuccessful, it may be necessary to ligature the femoral artery below the origin of the arteria profunda femoris, as ligature of the anterior and posterior tibial arteries may not be sufficient to control the hæmorrhage, and under the circumstances it is safer and quicker to tie the femoral artery.

THE VEINS

The veins convey the blood from the different parts of the body to the heart. They receive the blood from the capillaries, and unite with one another to form larger vessels which, in their passage towards the heart, increase in size as they receive tributaries, or join other veins. The veins are larger and more numerous than the arteries; hence, the capacity of the veins is greater than that of the arteries; the capacity of the pulmonary veins, however, only slightly exceeds that of the pulmonary arteries. The veins are cylindrical like the arteries; their walls, however, are thin and they collapse when the vessels are empty, and the uniformity of their surfaces is interrupted at intervals by slight constrictions, which indicate the existence of valves in their interior (p. 573). They communicate very freely with one another, especially in certain regions of the body. Thus, between the venous sinuses of the cranium, and between the veins of the neck, where obstruction would be attended with imminent danger to the cerebral circulation, frequent anastomoses are found. Free communications also exist between the veins of the vertebral canal, and between the veins composing the various venous plexuses in the abdomen and pelvis.

The veins consist of two sets, *pulmonary* and *systemic*.

The **pulmonary veins**, unlike other veins, contain arterial blood which they return from the lungs to the left atrium of the heart.

The **systemic venous channels** return the venous blood from the body generally, to the right atrium of the heart, and are subdivided into three sets, viz. superficial and deep veins, and venous sinuses.

The **superficial veins** lie in the superficial fascia, beneath the skin; they return the blood from these structures, and eventually join the deep veins.

The **deep veins** accompany the arteries, and are usually enclosed in the same sheaths with those vessels. With the smaller arteries—as the radial, ulnar, brachial, tibial, peronæal—they exist generally in pairs, one lying on either side of the artery, and are called *venæ comitantes*. The larger arteries—such as the axillary, subclavian, popliteal, and femoral—have usually only one accompanying vein. In certain regions, however, the deep veins do not accompany the arteries; for instance, the cerebral veins, the veins of the skull and vertebral canal, the hepatic veins in the liver, and the larger veins returning blood from the bones.

Venous sinuses are found only in the interior of the skull, and are canals between the two layers of the dura mater.

The **portal vein**, an appendage to the systemic venous system, is confined to the abdominal cavity, and conveys the venous blood from the spleen and the viscera of digestion to the liver, where it breaks up into a network of capillary-like vessels, from which the blood is drained by the hepatic veins to the inferior vena cava.

THE PULMONARY VEINS

The **pulmonary veins** return the arterialised blood from the lungs to the left atrium of the heart. They are four in number, two from each lung, and are destitute of valves. They commence in the capillary network on the walls of the alveoli of the lungs, and, joining together, form one vessel from each lobule of the lung. These vessels, uniting successively, form a single trunk from each lobe, three from the right lung and two from the left. The vein from the middle lobe of the right lung generally unites with that from the upper lobe, so that ultimately two veins, a superior and an inferior, leave each lung; they perforate the fibrous layer of the pericardium and open separately into the upper and posterior part of the left atrium. Occasionally the three veins on the right side remain separate. Sometimes the two left pulmonary veins end by a common opening.

In the root of the lung, the superior pulmonary vein lies in front of and a little below the pulmonary artery; the inferior is situated at the lowest part of the hilum of the lung and on a plane posterior to that of the superior vein. Behind the pulmonary artery is the bronchus.

On the right side the upper pulmonary vein passes behind the superior vena cava, and the lower behind the right atrium.

On the left side both pulmonary veins pass in front of the descending thoracic aorta.

Within the pericardium, their anterior surfaces are invested by the serous layer of this membrane.

THE SYSTEMIC VEINS

The **systemic veins** may be arranged into three groups: 1. The veins of the heart. 2. The veins of the upper extremities, head, neck, and thorax, which end in the superior vena cava. 3. The veins of the lower extremities, abdomen, and pelvis, which end in the inferior vena cava.

THE VEINS OF THE HEART

The **coronary sinus.**—Most of the veins of the heart open into the coronary sinus. This is a wide venous channel about 2 or 3 cm. long, situated in the posterior part of the coronary sulcus of the heart (fig. 727), between the left atrium and left ventricle, and covered by muscular fibres from the left atrium. It ends in the right atrium between the opening of the inferior vena cava and the atrioventricular orifice, its aperture being guarded by a semilunar valve, the *valve of the coronary sinus* (valve of Thebesius).

Its tributaries are the great, small, and middle cardiac veins, the posterior vein of the left ventricle, and the oblique vein of the left atrium, all of which, except the last, are provided with valves at their orifices.

1. The **great cardiac vein** (fig. 727) begins at the apex of the heart and ascends in the anterior longitudinal sulcus to the bases of the ventricles. It then curves to the left in the coronary sulcus, and, reaching the back of the heart, opens into the left extremity of the coronary sinus. It receives tributaries from the left atrium and from both ventricles: one, the *left marginal vein,* is of considerable size, and ascends along the left margin of the heart.

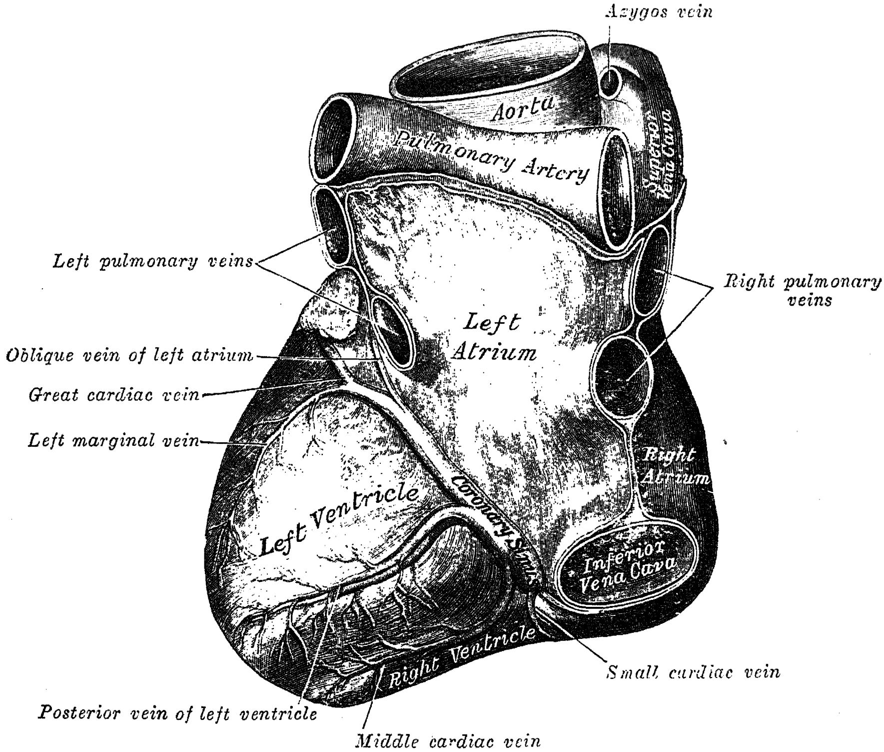
2. The **small cardiac vein** (fig. 727) runs in the coronary sulcus between the right atrium and ventricle, and opens into the right extremity of the coronary sinus. It receives blood from the back of the right atrium and ventricle; the *right marginal vein* ascends along the right margin of the heart and joins the small cardiac vein in the coronary sulcus, or opens directly into the right atrium.

3. The **middle cardiac vein** (fig. 727) begins at the apex of the heart, ascends in the posterior longitudinal sulcus, and ends in the coronary sinus near its right extremity.

4. The **posterior vein of the left ventricle** (fig. 727) runs on the diaphragmatic surface of the left ventricle a little to the left of the middle cardiac vein; it usually opens into the coronary sinus, but may end in the great cardiac vein.

5. The **oblique vein of the left atrium** (oblique vein of Marshall) (fig. 727) is a small vessel which descends obliquely on the back of the left atrium and ends in the coronary sinus near its left extremity; it is continuous above with the *ligament of the left vena cava* (vestigial fold of Marshall), and the two structures are remnants of the left duct of Cuvier.

FIG. 727.—The base and the diaphragmatic surface of the heart.



The following cardiac veins do not end in the coronary sinus: (1) the **anterior cardiac veins**, comprising three or four small vessels which collect blood from the front of the right ventricle and open into the right atrium; the right marginal vein frequently opens into the right atrium, and is therefore sometimes regarded as belonging to this group; (2) the **smallest cardiac veins** (vv. cordis minimæ), consisting of a number of minute veins which lie in the muscular wall of the heart and open directly into its cavities, most of them into the atria, but a few into the ventricles.

THE VEINS OF THE HEAD AND NECK

The veins of the head and neck may be subdivided into three groups: 1. The veins of the exterior of the head and face. 2. The veins of the neck. 3. The diploic veins, the veins of the brain, and the venous sinuses of the dura mater.

THE VEINS OF THE EXTERIOR OF THE HEAD AND FACE (fig. 728)

Frontal.	Superficial temporal.
Supra-orbital.	Internal maxillary.
Angular.	Posterior facial.
Anterior facial.	Posterior auricular.

Occipital.

The **frontal vein** begins on the forehead in a venous network which communicates with the frontal tributaries of the superficial temporal vein. Veins converge

from the network to form a single trunk, which descends near the middle line of the forehead parallel with the vein of the opposite side. At the root of the nose the two frontal veins are joined by a transverse branch which is called the *nasal arch*, and receives small veins from the dorsum of the nose. The frontal veins then diverge, and at the medial angle of the orbit, each joins with the *supra-orbital vein* to form the *angular vein*. Occasionally the frontal veins unite in a single trunk, which divides at the root of the nose into the two angular veins.

The **supra-orbital vein** begins near the zygomatic process of the frontal bone, where it communicates with the superficial and middle temporal veins. It courses medialwards along the upper margin of the orbit beneath the Orbicularis oculi, and, at the medial angle of the orbit, pierces this muscle and unites with the frontal vein to form the *angular vein*. It sends a branch through the supra-orbital notch into the orbital cavity to join the superior ophthalmic vein; as this branch traverses the supra-orbital notch it is joined by the frontal diploic vein.

The **angular vein**, formed by the junction of the frontal and supra-orbital veins, runs obliquely downwards on the side of the root of the nose, to the level of the lower margin of the orbit, where it becomes the anterior facial vein. It receives the veins of the ala nasi, and communicates with the superior ophthalmic vein. Through the communication of the superior ophthalmic vein with the supra-orbital and angular veins, an anastomosis is established between the anterior facial vein and the cavernous sinus.

The **anterior facial vein** (facial vein) (fig. 728) begins at the side of the nose as a direct continuation of the angular vein. It runs downwards and backwards behind the external maxillary (facial) artery, but follows a less tortuous course. It passes beneath the Zygomaticus, Risorius and Platysma, descends along the anterior border and then on the superficial surface of the Masseter, crosses over the body of the mandible, and runs obliquely backwards, beneath the Platysma and superficial to the submaxillary gland, Digastricus, and Stylohyoideus. It unites with the anterior branch of the posterior facial vein to form the *common facial vein*, which enters the internal jugular vein at a variable point below the hyoid bone. From near the termination of the common facial vein a branch of considerable size often runs down the anterior border of the Sternocleidomastoideus to join the lower part of the anterior jugular vein.

Tributaries.—The anterior facial vein receives a large branch, the *deep facial vein*, from the pterygoid venous plexus. It is also joined by the inferior palpebral, the superior and inferior labial, the buccinator and the masseteric veins. Below the mandible it receives the submental, palatine, and submaxillary veins, and, generally also, the vena comitans of the hypoglossal nerve.

Applied Anatomy.—There are some points about the anterior facial vein which render it of great importance in surgery. It is not so flaccid as are most superficial veins, and, in consequence of this, remains more patent when divided. It has, moreover, no valves. It communicates freely with the intracranial circulation, not only at its commencement by the angular and supra-orbital veins which are connected with the ophthalmic vein, a tributary of the cavernous sinus, but also by the deep facial vein, which communicates through the pterygoid plexus with the cavernous sinus by branches passing through the foramen ovale and foramen lacerum (p. 724). These facts have an important bearing upon the surgery of some diseases; any phlegmonous inflammation of the face following a poisoned wound is liable to set up thrombosis in the anterior facial vein, and detached portions of the clot may give rise to purulent foci in other parts of the body. These thrombi may extend upwards into the cranial sinuses, and so induce a fatal issue; this has been known to follow in cases of ordinary carbuncle of the face. The position of the vein must be borne in mind when incisions are made for the relief of suppuration about the mandible.

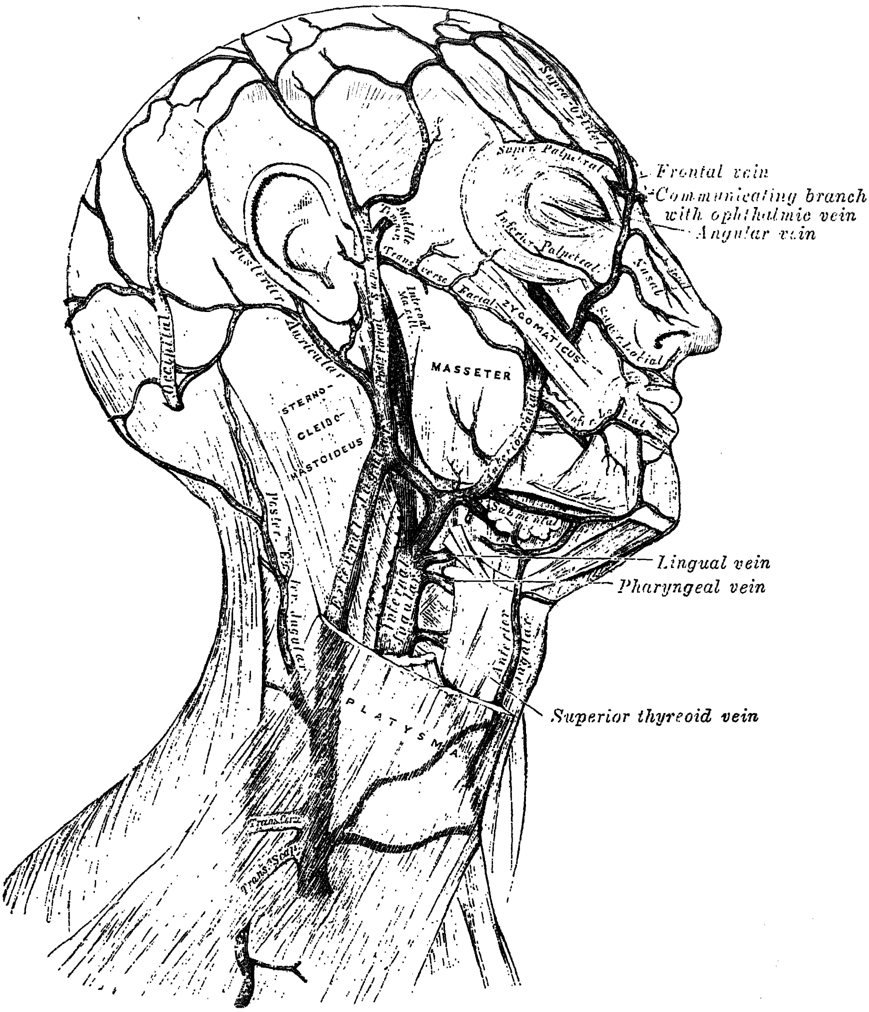
The **superficial temporal vein** (fig. 728) begins on the side and vertex of the skull in a network which joins with the corresponding vein of the opposite side, and with the frontal, supra-orbital, posterior auricular and occipital veins. From this network, frontal and parietal branches arise, and unite above the zygomatic arch to form the superficial temporal vein, which is joined in this situation by the *middle temporal vein*. It then crosses the posterior root of the zygomatic arch, enters the substance of the parotid gland, and unites with the internal maxillary vein to form the posterior facial vein.

Tributaries.—The superficial temporal vein receives some veins from the parotid gland, articular veins from the mandibular joint, anterior auricular veins from

the auricula, and the *transverse facial* from the side of the face. The middle temporal vein, after receiving the *orbital vein* which is formed by some lateral palpebral branches, passes backwards between the layers of the temporal fascia to join the superficial temporal vein.

The **pterygoid plexus** is of considerable size, and is situated partly between the Temporalis and Pterygoideus externus, and partly between the two Pterygoidei. It receives the sphenopalatine, deep temporal, pterygoid, masseteric, buccinator,

FIG. 728.—The veins of the right side of the head and neck.



alveolar, and some palatine veins, and a branch or branches from the inferior ophthalmic vein. The pterygoid plexus anastomoses with the anterior facial vein, through the deep facial vein; it is also connected with the cavernous sinus by veins which pass through the foramen Vesalii, foramen ovale, and foramen lacerum.

The **internal maxillary vein** is a short trunk which accompanies the first part of the internal maxillary artery and is formed by a confluence of the veins of the pterygoid plexus. It passes backwards between the sphenomandibular ligament and the neck of the mandible, and unites with the temporal vein to form the posterior facial vein.

The **posterior facial vein** (temporomaxillary vein), formed by the union of the superficial temporal and internal maxillary veins, descends in the substance of

the parotid gland, superficial to the external carotid artery but deep to the facial nerve, between the ramus of the mandible and the Sternocleidomastoideus. It divides into two branches, an anterior, which passes forwards and unites with the anterior facial vein to form the common facial vein, and a posterior, which is joined by the posterior auricular vein and becomes the external jugular vein.

The **posterior auricular vein** (fig. 728) begins on the posterior part of the side of the head, in a network which communicates with the tributaries of the occipital and superficial temporal veins. It descends behind the auricula, and joins the posterior division of the posterior facial vein to form the external jugular vein. It receives the stylomastoid vein and some tributaries from the cranial surface of the auricula.

The **occipital vein** begins in a venous network at the posterior part of the skull. It pierces the cranial attachment of the Trapezius, dips into the suboccipital triangle and joins the deep cervical and vertebral veins. Occasionally it follows the course of the occipital artery and ends in the internal jugular vein; sometimes it joins the posterior auricular vein and through it opens into the external jugular vein. The parietal emissary vein connects it with the superior sagittal sinus, and the mastoid emissary vein with the transverse sinus. The occipital diploic vein sometimes joins it.

The Veins of the Neck (figs. 728, 729)

External jugular.	Anterior jugular.
Posterior external jugular.	Internal jugular.
Vertebral.	

The **external jugular vein** (fig. 728) receives the greater part of the blood from the exterior of the cranium and from the deep parts of the face, and is formed by the union of the posterior division of the posterior facial vein with the posterior auricular vein. It begins in the substance of the parotid gland, on a level with the angle of the mandible, and runs down the neck, where its course is represented by a line drawn from the angle of the mandible to the middle of the clavicle. It crosses the Sternocleidomastoideus obliquely, and in the subclavian triangle perforates the deep fascia, and ends in the subclavian vein, lateral to or in front of the Scalenus anterior; the wall of the vein is adherent to the circumference of the opening in the deep fascia. It is covered by the Platysma, superficial fascia, and skin, and separated from the Sternocleidomastoideus by the investing layer of the deep cervical fascia; it crosses the cutaneous cervical nerve, and its upper half runs parallel with the great auricular nerve. The external jugular vein varies in size, bearing an inverse proportion to the other veins of the neck; it is occasionally double. It is provided with two pairs of valves, a lower pair at its entrance into the subclavian vein, an upper about 4 cm. above the clavicle. The portion of the vein between the two sets of valves is often dilated, and is termed the *sinus*. These valves do not prevent regurgitation of the blood, or the passage of injection from below upwards.

Tributaries.—The external jugular vein receives the posterior external jugular, and, near its termination, the transverse cervical, transverse scapular, and anterior jugular veins; in the parotid gland it is joined by a large branch from the internal jugular vein. The occipital vein occasionally opens into it.

The **posterior external jugular vein** begins in the occipital region and returns the blood from the skin and superficial muscles in the upper and posterior part of the neck. It opens into the middle part of the external jugular vein.

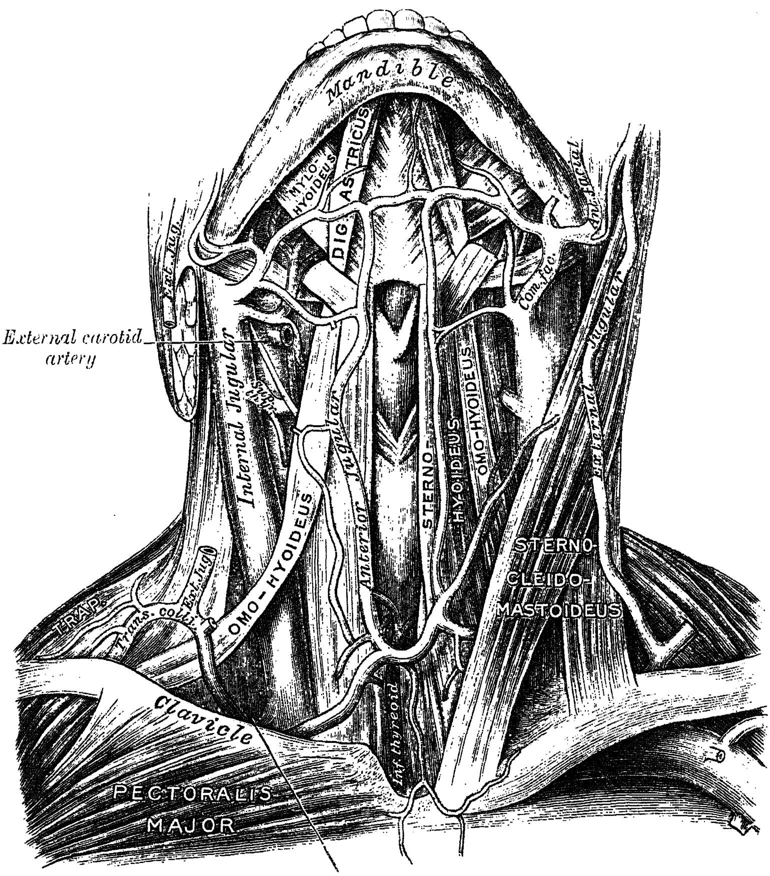
The **anterior jugular vein** (figs. 728, 729) is devoid of valves and begins near the hyoid bone by the confluence of several superficial veins from the submaxillary region. It descends between the median line and the anterior border of the Sternocleidomastoideus; at the lower part of the neck it turns lateralwards beneath that muscle, but superficial to the depressors of the hyoid bone, and opens into the termination of the external jugular vein, or into the subclavian vein. Its size varies considerably, and usually bears an inverse proportion to that of the external jugular vein. It communicates with the internal jugular vein and receives as tributaries some laryngeal veins, and occasionally a small thyreoid vein. There are usually two anterior jugular veins, a right and a left; just above the sternum they are united by a large transverse trunk, the *venous jugular arch*, which receives

tributaries from the inferior thyreoid veins. The anterior jugular veins may be replaced by a single trunk which descends in the middle line of the neck.

Applied Anatomy.—Venesection used formerly to be performed on the external jugular vein, but is now probably never resorted to. When the vein is cut there is some risk of air being drawn into it.

The **internal jugular vein** (fig. 729) collects the blood from the brain, from the superficial parts of the face, and from the neck. It begins at the base of the skull in the posterior compartment of the jugular foramen, where it is directly continuous

FIG. 729.—The veins of the neck. Anterior aspect. (After Spalteholz.)



with the transverse sinus. At its origin it is somewhat dilated; this dilatation is called the *superior bulb* and lies below the posterior part of the floor of the tympanic cavity. The vein runs down the side of the neck under cover of the Sternocleido-mastoideus, lying at first lateral to the internal carotid artery, and then lateral to the common carotid artery. At the root of the neck it unites with the subclavian vein to form the innominate vein. The internal jugular vein is dilated near its termination to form what is known as the *inferior bulb*; directly above this bulb the vein contains a pair of valves. In the upper part of its course, it lies upon the Rectus capitis lateralis, behind the internal carotid artery and the nerves passing through the jugular foramen; lower down, the vein and artery lie upon the same plane, the glossopharyngeal and hypoglossal nerves passing forwards between them; the vagus nerve descends in the same sheath as the vein and artery, but lies between and on a plane posterior to them; the accessory nerve runs obliquely backwards,

about 28 per cent. of subjects the pubic branch is large, and takes the place of the obturator artery (p. 680).

Branches are distributed to the abdominal muscles and the peritoneum, and anastomose with the iliac circumflex and lumbar arteries.

Cutaneous branches perforate the tendon of the Obliquus externus abdominis, supply the skin and anastomose with branches of the superficial epigastric artery.

Peculiarities.—The inferior epigastric artery may spring from any part of the external iliac artery between the inguinal ligament and a point 6 cm. above it; or it may arise below this ligament, from the femoral artery. It frequently springs from the external iliac artery, by a common trunk with the obturator artery. Sometimes it arises from the obturator artery, or it may be formed of two branches, one from the external iliac artery, the other from the hypogastric artery.

Applied Anatomy.—The inferior epigastric artery has important surgical relations, and is one of the principal means, through its anastomosis with the internal mammary, of establishing the collateral circulation after ligature of either the common or external iliac arteries. It lies close to the abdominal inguinal ring, and is therefore *medial* to an oblique inguinal hernia, but *lateral* to a direct inguinal hernia, as these emerge from the abdomen. It forms the lateral boundary of Hesselbach's triangle, and is in close relationship with the spermatic cord, which lies in front of it in the inguinal canal, separated only by the transversalis fascia. The ductus deferens hooks round its lateral side.

The **deep iliac circumflex artery** arises from the lateral side of the external iliac artery nearly opposite the inferior epigastric artery. It ascends obliquely behind the inguinal ligament, in a sheath formed by the junction of the transversalis and iliac fasciæ, to the anterior superior iliac spine, where it anastomoses with the ascending branch of the lateral femoral circumflex artery. It then pierces the transversalis fascia and passes along the inner lip of the crest of the ilium to about its middle, where it perforates the Transversus abdominis and runs backwards between that muscle and the Obliquus internus, to anastomose with the iliolumbar and superior glutæal arteries. Opposite the anterior superior iliac spine it gives off a large branch (fig. 557), which ascends between the Obliquus internus and Transversus, supplying them, and anastomosing with the lumbar and inferior epigastric arteries.

THE ARTERIES OF THE LOWER EXTREMITY

The chief artery of the lower extremity is a direct continuation of the external iliac. It extends from the level of the inguinal ligament to the lower border of the Popliteus, where it divides into the anterior and posterior tibial arteries. Its upper part is named the femoral artery, its lower the popliteal artery.

The Femoral Artery (figs. 714, 716)

The **femoral artery** is the continuation of the external iliac artery. It begins behind the inguinal ligament, midway between the anterior superior iliac spine and the symphysis pubis, and passes down the front and medial side of the thigh. It ends at the junction of the middle with the lower one-third of the thigh where it passes through an opening in the Adductor magnus to become the popliteal artery. The first 3 cm. or 4 cm. of the vessel are enclosed, together with the femoral vein, in the *femoral sheath.* The upper part of the femoral artery is contained in the *femoral triangle* (Scarpa's triangle), the lower part in the *adductor canal* (Hunter's canal).

The **femoral sheath** (figs. 710, 711) is formed by a prolongation downwards, behind the inguinal ligament, of the fasciæ which line the abdomen, the transversalis fascia being continued down in front of the femoral vessels and the iliopectineal fascia behind them. The sheath has the form of a short funnel, the wide end of which is directed upwards, while the lower, narrow end fuses with the fascial investment of the vessels, about 3 or 4 cm. below the inguinal ligament. The lateral wall of the sheath is vertical and is perforated by the lumbo-inguinal nerve; the medial wall is directed obliquely downwards and lateralwards, and is pierced by the great saphenous vein and by some lymphatic vessels. The sheath is divided by two vertical partitions which

level with the greater cornu of the hyoid bone. The vein should be ligatured in two places and divided between. After the vessel has been secured and divided, the transverse sinus is to be thoroughly cleared out, and, by removing the ligature from the upper end of the divided vein, all septic clots removed by syringing from the sinus through the vein. If hæmorrhage occur from the distal end of the sinus, it can be arrested by careful plugging with gauze between the sinus and the bone. When the thrombosis involves the superior bulb of the internal jugular vein, the glossopharyngeal, vagus and accessory nerves may be paralysed. The hypoglossal nerve is sometimes paralysed by extension of the thrombus to the veins of the hypoglossal canal.

The internal jugular vein is also surgically important, because it is surrounded by a number of deep cervical lymph-glands; and when these are enlarged in tuberculous or malignant disease, they are apt to adhere to the vessel, rendering their removal difficult and often dangerous. The proper course to pursue in these cases is to ligature the vessel above and below the glandular mass, and remove the included portion with the glands.

Cardiac pulsation is often demonstrable in the internal jugular vein at the root of the neck. There are no valves in the innominate veins or superior vena cava; in consequence, the systole of the right atrium causes a wave to pass up these vessels, and when the conditions are favourable this wave appears as a somewhat feeble flicker over the internal jugular vein at the root of the neck, quite distinct from, and just preceding, the more forcible impulse transmitted from the underlying common carotid artery and due to the ventricular systole. This atrial systolic venous impulse is much increased in conditions in which the right atrium is abnormally distended with blood or is hypertrophied, as is often the case in disease of the bicuspid valve. In the Adams-Stokes' syndrome (p. 591) it is this pulsation which gives evidence of the fact that the atria are beating faster—often two or three times faster—than the ventricles.

The **vertebral vein** is formed in the suboccipital triangle, from numerous small tributaries which spring from the internal vertebral venous plexuses and issue from the vertebral canal above the posterior arch of the atlas. They unite with small veins from the deep muscles at the upper part of the back of the neck, and form a vessel which enters the foramen in the transverse process of the atlas, and descends, forming a dense plexus around the vertebral artery, in the canal formed by the foramina transversaria of the cervical vertebræ. This plexus ends in the vertebral vein, which emerges from the foramen transversarium of the sixth cervical vertebra, and opens into the upper and posterior part of the innominate vein, the opening being guarded by a pair of valves. On the right side, it crosses the first part of the subclavian artery.

Tributaries.—The vertebral vein communicates with the transverse sinus of the skull by a vein which passes through the condyloid canal, when that canal exists. It receives branches from the occipital vein, from the prevertebral muscles, and from the internal and external vertebral venous plexuses. It is joined by the anterior vertebral and the deep cervical veins ; close to its termination it sometimes receives the first intercostal vein.

The **anterior vertebral vein** commences in a plexus around the transverse processes of the upper cervical vertebræ, descends in company with the ascending cervical artery between the Scalenus anterior and Longus capitis, and opens into the terminal part of the vertebral vein.

The **deep cervical vein** accompanies its artery between the Semispinales capitis et colli. It begins in the suboccipital region by communicating branches from the occipital vein and by small veins from the deep muscles at the back of the neck. It receives tributaries from the plexuses around the spinous processes of the cervical vertebræ, and passes forwards between the transverse process of the seventh cervical vertebra and the neck of the first rib to end in the lower part of the vertebral vein.

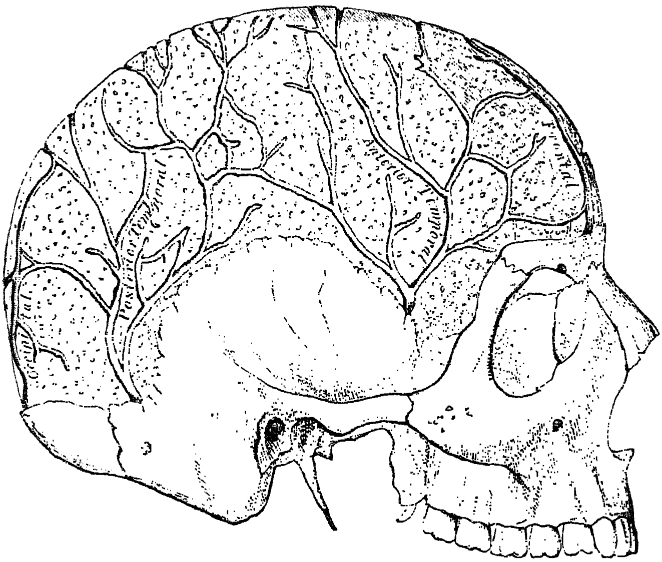
The Diploic Veins (fig. 731)

The **diploic veins** occupy channels in the diploë of the cranial bones and are devoid of valves. They are large, and exhibit at irregular intervals pouch-like dilatations; their walls are thin, and formed of endothelium supported by a layer of elastic tissue.

They communicate with the meningeal veins, the sinuses of the dura mater, and the veins of the pericranium. They consist of (1) the *frontal diploic vein*, which emerges from the bone at the supra-orbital foramen, and opens into the supra-orbital vein ; (2) the *anterior temporal diploic vein*, which is confined chiefly to the frontal bone, and pierces the great wing of the sphenoidal bone

to end in the sphenoparietal sinus or in the anterior deep temporal vein ; (3) the *posterior temporal diploic vein*, which is situated in the parietal bone ; it descends to the mastoid angle of the parietal bone and joins the transverse sinus through

Fig. 731.—The veins of the diploë. Displayed by the removal of the outer table of the skull.



an aperture at the mastoid angle of the parietal bone or through the mastoid foramen ; and (4) the *occipital diploic vein*, the largest of the four, which is confined to the occipital bone, and opens into the occipital vein, or into the transverse sinus near the confluence of the sinuses.

The Veins of the Brain

The veins of the brain possess no valves, and their walls, owing to the absence of muscular tissue, are extremely thin. They pierce the arachnoid membrane and the inner or meningeal layer of the dura mater, and open into the cranial venous sinuses. They consist of two sets, cerebral and cerebellar.

The **cerebral veins** are divisible into external and internal groups according as they drain the outer surfaces or the inner parts of the hemispheres.

The **external cerebral veins** are the superior, middle, and inferior.

The *superior cerebral veins*, eight to twelve in number, drain the superior, lateral, and medial surfaces of the hemispheres, and are mainly lodged in the sulci between the gyri, but some run across the gyri. They open into the superior sagittal sinus ; the anterior veins run nearly at right angles to the sinus ; the posterior and larger veins are directed obliquely forwards, and thus open into the sinus in a direction opposed to the current of the blood contained within it.

The *middle cerebral veins* (superficial Sylvian veins) are two in number. Each begins on the lateral surface of the hemisphere, and, running along the lateral cerebral fissure, ends in the cavernous sinus. Each is connected (*a*) with the superior sagittal sinus by the *great anastomotic vein of Trolard*, which opens into one of the superior cerebral veins ; (*b*) with the transverse sinus by the *posterior anastomotic vein of Labbé*, which courses over the temporal lobe.

The *inferior cerebral veins*, of small size, drain the under surfaces of the hemispheres. Those on the orbital surfaces of the frontal lobes join the superior cerebral veins, and through these open into the superior sagittal sinus ; those of the temporal lobes anastomose with the basal and middle cerebral veins, and join the cavernous, superior petrosal and transverse sinuses.

The **basal veins** are two in number. Each begins at the anterior perforated substance by the union of (*a*) a small *anterior cerebral vein* which accompanies the anterior cerebral artery, (*b*) the *deep middle cerebral vein* (deep Sylvian vein), which receives tributaries from the insula and neighbouring gyri, and runs in the lower part of the lateral cerebral fissure, and (*c*) the *inferior striate veins* which leave the corpus striatum through the anterior perforated substance. The basal vein passes backwards round the cerebral peduncle, and ends in the internal cerebral vein (vein of Galen); it receives tributaries from the interpeduncular fossa, the inferior horn of the lateral ventricle, the hippocampal gyrus, and the mid-brain.

The **internal cerebral veins** (veins of Galen), two in number, drain the deep parts of the hemisphere; each is formed near the interventricular foramen by the union of the *terminal* and *chorioid veins*. They run backwards parallel with one another, between the layers of the tela chorioidea of the third ventricle, and beneath the splenium of the corpus callosum, where they unite to form a short trunk, the *great cerebral vein*; just before their union each receives the corresponding basal vein.

The *terminal vein* (vena corporis striati) runs in the groove between the corpus striatum and thalamus, receives numerous veins from both of these structures, and unites behind the crus fornicis with the chorioid vein, to form one of the internal cerebral veins. The *chorioid vein* runs along the whole length of the chorioid plexus, and receives veins from the hippocampus, the fornix, and the corpus callosum.

The **great cerebral vein** (vena magna Galeni), formed by the union of the two internal cerebral veins, is a short median trunk which curves backwards and upwards around the splenium of the corpus callosum and opens into the anterior extremity of the straight sinus.

The **cerebellar veins** are placed on the surface of the cerebellum, and consist of two sets, superior and inferior. The *superior cerebellar veins* pass partly forwards and medialwards, across the superior vermis, to end in the straight sinus and the internal cerebral veins, partly lateralwards to the transverse and superior petrosal sinuses. The *inferior cerebellar veins*, of large size, end in the transverse, superior petrosal, and occipital sinuses.

The Venous Sinuses of the Dura Mater (figs. 732 to 736)

The sinuses of the dura mater are venous channels which drain the blood from the brain; they are situated between the two layers of the dura mater and are lined by endothelium continuous with that which lines the veins; they contain no valves and their walls are devoid of muscular tissue. They may be divided into two groups: (1) a posterosuperior, at the upper and posterior parts of the skull, and (2) an antero-inferior, at the base of the skull.

1. The posterosuperior group of venous sinuses:

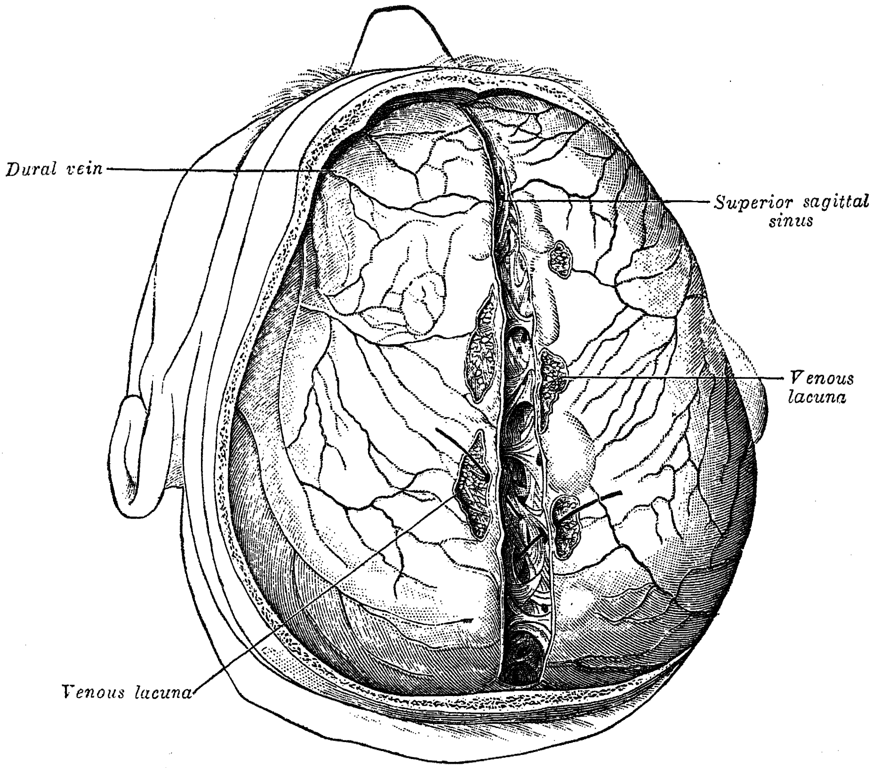
Superior sagittal.	Straight.
Inferior sagittal.	Two transverse.
Occipital.	

The **superior sagittal sinus** (superior longitudinal sinus) (figs. 732, 733) occupies the attached or convex margin of the falx cerebri. It commences in front of the crista galli, and receives through the foramen cæcum, if this foramen be patent, a vein from the nasal cavity; it runs backwards, grooving the inner surface of the frontal bone, the adjacent margins of the two parietal bones, and the superior division of the cruciate eminence of the occipital bone; near the internal occipital protuberance it deviates to one or other side (usually the right) and is continued as the corresponding transverse sinus. It is triangular in cross-section and gradually increases in size as it passes backwards. On its inner surface are the openings of the superior cerebral veins, and numerous fibrous bands (*chordæ Willisii*) which cross the inferior angle of the sinus; the sinus also communicates through small openings with irregularly-shaped *venous lacunæ* (lacunæ laterales) in the dura mater near the sinus. There are usually three lacunæ laterales on each side of the sinus: a small frontal, a large parietal, and an occipital which is intermediate in size between the other two (Sargent *).

* Percy Sargent, *Journal of Anatomy and Physiology*, vol. xlv.

Many fine fibrous bands cross the lacunæ, and numerous arachnoidal granulations (Pacchionian bodies) project into them from below. The superior sagittal sinus receives the superior cerebral veins, veins from the diploë and dura mater, and, near the posterior extremity of the sagittal suture, veins from the pericranium, which pass through the parietal foramina.

FIG. 732.—The superior sagittal sinus laid open after the removal of the skull-cap. The chordæ Willisii and venous lacunæ are clearly seen; from two of the lacunæ probes are passed into the sinus. (Poirier and Charpy.)



Clark* says the lacunæ lateralis should not be described as single well-defined cavities, but rather as a complicated meshwork of veins into which the diploic veins and the superior terminations of the meningeal veins open. He asserts that the superior cerebral veins never open into the lacunæ, but pass beneath them and open directly into the superior sagittal sinus.

Applied Anatomy.—The communications which take place between the superior sagittal sinus and the veins of the nose, scalp, and diploë, cause it to be at times the seat of infective thrombosis from suppurative processes in these parts.

The **inferior sagittal sinus** (inferior longitudinal sinus) (fig. 733) is contained in the posterior one-half or two-thirds of the free margin of the falx cerebri. It increases in size as it passes backwards, and ends in the straight sinus. It receives several veins from the falx cerebri, and occasionally a few from the medial surfaces of the hemispheres.

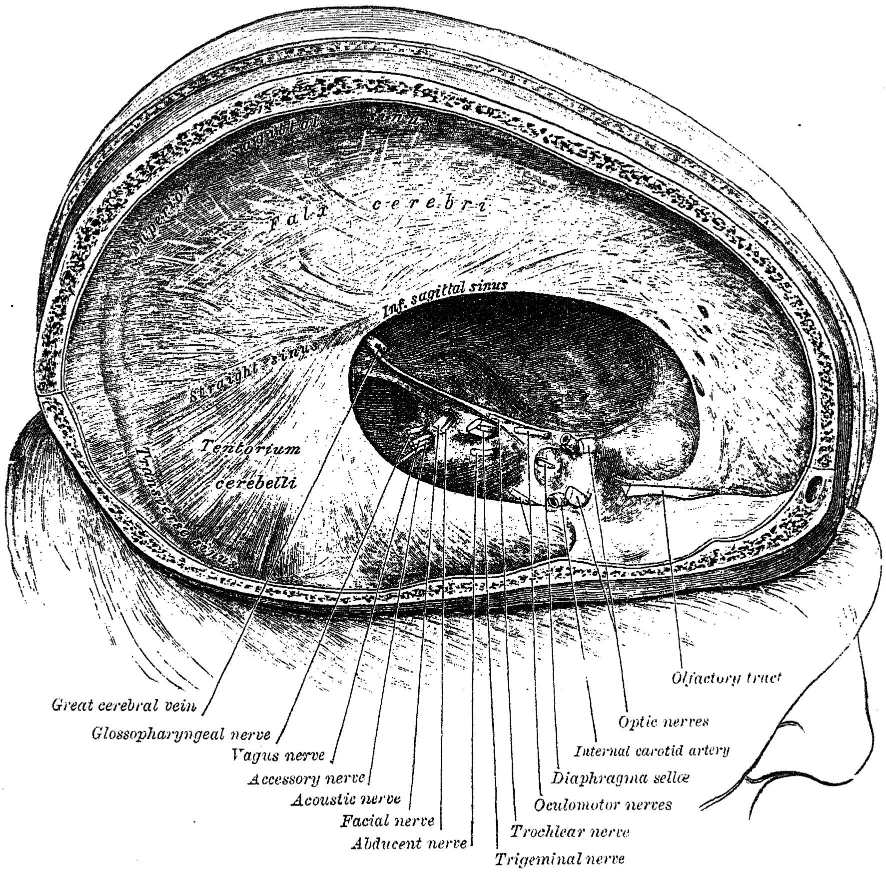
The **straight sinus** (figs. 733, 734) is situated in the line of junction of the falx cerebri with the tentorium cerebelli. It is triangular in cross-section, and is traversed by a few transverse bands. It runs backwards and downwards from the end of the inferior sagittal sinus to the transverse sinus of the side opposite to that into which the superior sagittal sinus is prolonged. Its terminal part communicates by a cross branch with the confluence of the sinuses. Besides the inferior sagittal sinus, it receives some of the superior cerebellar

* W. E. le Gros Clark, *Journal of Anatomy*, vol. lv.

veins, and, at its commencement, the great cerebral vein (vena magna Galeni), the site of opening of this vein being marked by a dilatation.

The **transverse sinuses** (lateral sinuses) (figs. 734, 735) are of large size, and begin at the internal occipital protuberance; one, generally the right, being the direct continuation of the superior sagittal sinus, the other of the straight sinus. Each transverse sinus passes lateralwards and forwards, describing a slight curve with its convexity upwards, to the base of the petrous portion of the temporal bone and lies, in this part of its course, in the attached

FIG. 733.—The dura mater and its processes. Exposed by removing part of the right half of the skull, and the brain.

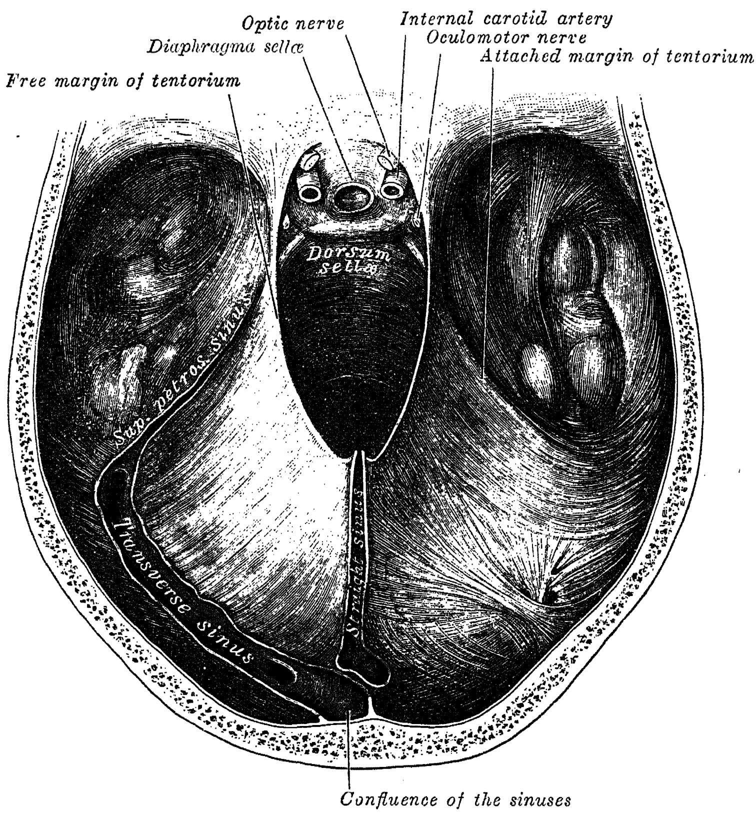


margin of the tentorium cerebelli; it then leaves the tentorium and curves downwards and medialwards to reach the posterior part of the jugular foramen, through which it passes, and ends in the internal jugular vein. It rests successively upon the squama of the occipital bone, the mastoid angle of the parietal bone, the mastoid part of the temporal bone, and the jugular process of the occipital bone; the portion which occupies the groove on the mastoid part of the temporal bone is sometimes termed the *sigmoid sinus*. The transverse sinuses are frequently of unequal size, that formed by the superior sagittal sinus being the larger; they increase in size as they proceed from behind forwards. On transverse section the horizontal portion of the sinus exhibits a prismoid, the curved portion a semicylindrical, form. They communicate with the veins of the pericranium by means of the mastoid and condyloid emissary veins, and receive the superior petrosal sinuses, some inferior cerebral, inferior cerebellar, and diploic veins, and the posterior anastomotic vein of

Labbé (p. 716). The *petrosquamous sinus*, when present, runs backwards along the junction of the squama and petrous portion of the temporal bone, and opens into the transverse sinus.

The **occipital sinus** (fig. 735), the smallest of the cranial sinuses, is situated in the attached margin of the falx cerebelli, and is generally single, but occasionally there are two. It commences around the margin of the foramen magnum by several small venous channels, one of which joins the terminal part of the transverse sinus; it communicates with the posterior internal vertebral venous plexuses, and ends in the confluence of the sinuses.

FIG. 734.—The tentorium cerebelli. Superior aspect.



The *confluence of the sinuses*, or *torcular Herophili*, is the term applied to the dilated extremity of the superior sagittal sinus. It is lodged on one side (generally the right) of the internal occipital protuberance, and from it the transverse sinus of the same side is derived. It receives also the blood from the occipital sinus, and is connected by a channel with the commencement of the opposite transverse sinus.

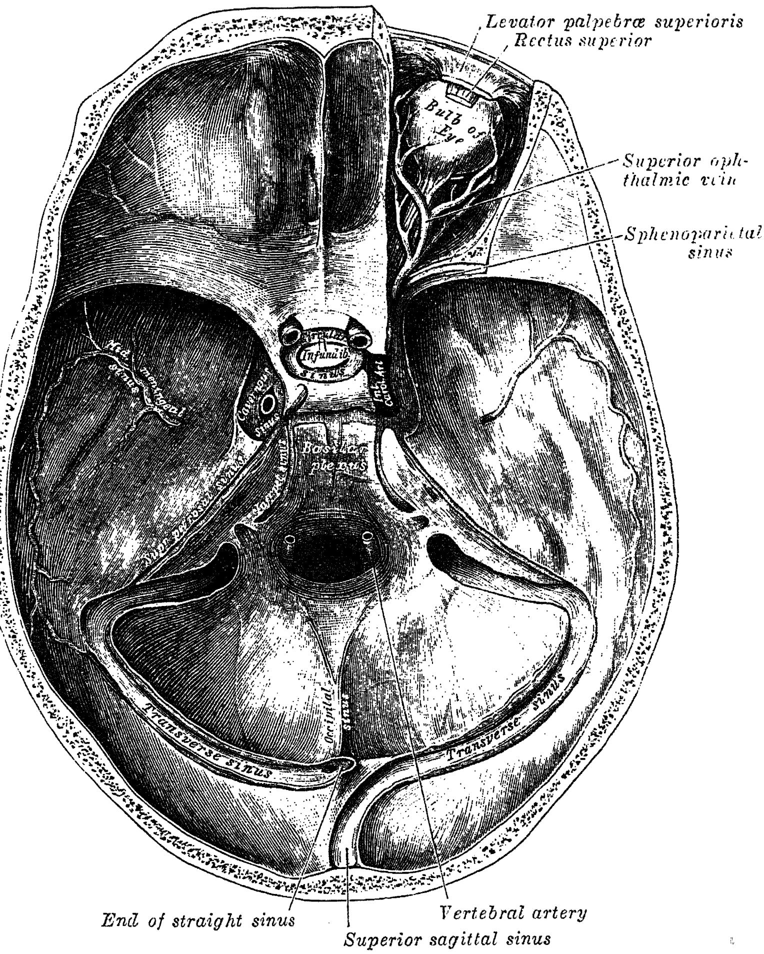
2. The antero-inferior group of venous sinuses:

Two cavernous.	Two inferior petrosal.
Two sphenoparietal.	Basilar plexus.
Two intercavernous.	Middle meningeal.
Two superior petrosal.	

The **cavernous sinuses** (figs. 735, 736) are placed on the sides of the body of the sphenoidal bone, and are so named because they present a reticulated structure, due to their being traversed by numerous interlacing filaments. Each extends from the superior orbital fissure in front, to the apex of the petrous part of the temporal bone behind, and has an average length of 2 cm. and a width of 1 cm. Passing through each sinus is the internal carotid artery,

surrounded by filaments of the carotid plexus; near to the lateral side of the artery is the abducent nerve; on the lateral wall of the sinus are the oculomotor and trochlear nerves, and the ophthalmic and maxillary divisions of the trigeminal nerve (fig. 736). These structures are separated from the blood in the sinus by the lining membrane of the sinus. Medial to the cavernous sinus are the sphenoidal air-sinus and the hypophysis (pituitary body); lateral to it, the temporal lobe of the cerebrum; posterior to it, the semilunar ganglion of the trigeminal nerve.

FIG. 735.—The sinuses at the base of the skull.



The tributaries of the cavernous sinus are the superior ophthalmic vein, a branch from the inferior ophthalmic vein, the middle cerebral or superficial Sylvian vein, some inferior cerebral veins, and the sphenoparietal sinus; the central vein of the retina sometimes opens into it. The cavernous sinus communicates with the transverse sinus through the superior petrosal sinus; with the internal jugular vein through the inferior petrosal sinus and a plexus of veins on the internal carotid artery; with the pterygoid venous plexus by veins which pass through the foramen Vesalii, foramen ovale, and foramen lacerum; and with the angular vein through the superior ophthalmic vein. The two sinuses also communicate with each other by means of the anterior and posterior intercavernous sinuses and the basilar plexus.

The **sphenoparietal sinuses** course along the under surfaces of the small wings of the sphenoidal bone, near their posterior edges. Each sinus receives some small veins from the adjacent part of the dura mater and may receive

one of the middle meningeal sinuses; it opens into the anterior part of the cavernous sinus.

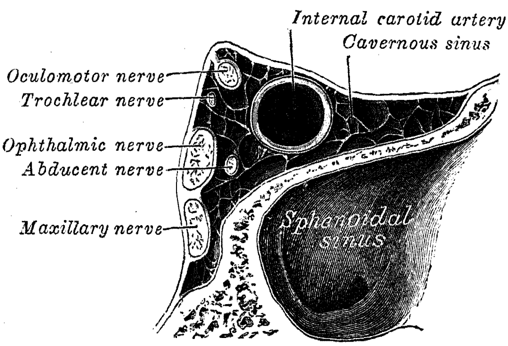
Applied Anatomy.—An arteriovenous communication may be established between the cavernous sinus and the internal carotid artery, giving rise to a pulsating tumour in the orbit. Such communication may be the result of a bullet wound, a stab, or a blow or fall sufficiently severe to cause a fracture of the base of the skull in this situation. The symptoms are sudden noise and pain in the head, followed by exophthalmos, swelling and congestion of the eyelids and conjunctivæ, and development of a pulsating tumour at the margin of the orbit, with thrill and the characteristic bruit; accompanying these symptoms there may be impairment of sight, paralysis of the iris and orbital muscles, and pain of varying intensity. In some cases the opposite orbit becomes affected by the passage of the arterial blood into the opposite sinus by means of the intercavernous sinuses; or the arterial blood may find its way through the emissary veins (p. 724) into the pterygoid plexus, and thence into the veins of the face. Pulsating tumours of the orbit may also be due to traumatic aneurysm of one of the orbital arteries, and symptoms resembling those of pulsating tumour may be produced by the pressure of an aneurysm of the internal carotid artery upon the ophthalmic veins as they enter the sinus. Ligature of the internal or common carotid artery has been performed in these cases with considerable success.

It is now well known that caries in the upper parts of the nasal cavities and suppuration in certain of the accessory sinuses of the nose are frequently responsible for septic thrombosis of the cavernous sinuses, in exactly the same way as thrombosis of the transverse sinus is due to septic disease in the mastoid process. Many deaths from meningitis, hitherto unaccounted for, are in reality due to the spread of an infection from the ethmoidal or sphenoidal air-sinuses to the cavernous sinuses, and thence to the meninges.

The **ophthalmic veins** (fig. 737), two in number, superior and inferior, are devoid of valves.

The *superior ophthalmic vein* begins behind the medial angle of the upper eyelid by the union of two branches which communicate anteriorly with the angular and supra-orbital veins (p. 710). It runs alongside the ophthalmic artery, receives tributaries corresponding to the branches of that vessel, passes through the medial part of the superior orbital fissure, and ends in the cavernous sinus.

Fig. 736.—An oblique section through the left cavernous sinus.



The *inferior ophthalmic vein* begins in a venous network at the fore part of the floor and medial wall of the orbit; it receives some veins from the Rectus inferior, Obliquus inferior, lacrimal sac and eyelids, and runs backwards above the Rectus inferior. It frequently joins the superior ophthalmic vein, but may open into the cavernous sinus. It communicates with the pterygoid venous plexus by means of small veins which pass through the inferior orbital fissure.

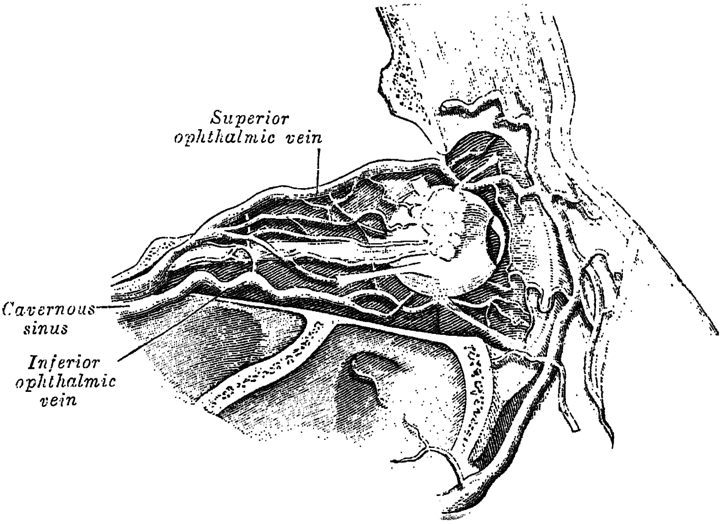
The **intercavernous sinuses**, an anterior and a posterior, connect the cavernous sinuses across the middle line, and are situated in the anterior and posterior borders of the diaphragma sellæ; they form with the cavernous sinuses a venous circle (*circular sinus*) (fig. 735); the posterior intercavernous sinus is sometimes absent.

The **superior petrosal sinuses** (fig. 735), small and narrow, drain the cavernous sinuses into the transverse sinuses. Each runs lateralwards and backwards, from the posterosuperior part of the corresponding cavernous sinus, over the trigeminal nerve, and lies in the attached margin of the tentorium cerebelli and in the superior petrosal sulcus of the temporal bone; it joins the transverse sinus where the latter curves downwards on the inner surface of the mastoid part of the temporal bone. It receives some cerebellar and inferior cerebral veins, and veins from the tympanic cavity.

The **inferior petrosal sinuses** drain the cavernous sinuses into the internal jugular vein. Each (fig. 735) begins in the postero-inferior part of the corresponding cavernous sinus, runs backwards in a groove between the petrous part of the temporal bone and the basilar part of the occipital bone, and, passing through the anterior part of the jugular foramen, ends in the superior bulb of the internal jugular vein. It receives the internal auditory veins and also veins from the medulla oblongata, pons, and under surface of the cerebellum.

The relations of the structures transmitted through the jugular foramen are as follows: the inferior petrosal sinus lies medially and anteriorly with the meningeal branch of the ascending pharyngeal artery, and is directed obliquely downwards and backwards; the transverse sinus is situated at the lateral and posterior part of the foramen with a meningeal branch of the occipital artery; between the two sinuses are the glossopharyngeal, vagus, and accessory

FIG. 737.—The veins of the orbit. (Poirier and Charpy.)



nerves. These three sets of structures are divided from each other by two processes of the dura mater. The junction of the inferior petrosal sinus with the internal jugular vein takes place on the lateral aspect of the nerves.

The **basilar plexus** (fig. 735) consists of several interlacing venous channels situated between the layers of the dura mater over the basilar part of the occipital bone; it connects the two inferior petrosal sinuses, and communicates with the anterior internal vertebral venous plexus.

The **middle meningeal sinuses** (middle meningeal veins) (fig. 735) accompany the branches of the middle meningeal arteries. They communicate above with the superior sagittal sinus and adjoining venous lacunæ, and unite to form two principal trunks, an anterior and a posterior, which accompany more or less closely the branches of the middle meningeal arteries in the grooves on the inner surface of the parietal bone; sometimes they occupy grooves apart from the arteries. Their mode of ending is subject to some variation. The posterior trunk may leave the cranial cavity through the foramen spinosum and open into the pterygoid venous plexus. The anterior trunk may reach the pterygoid plexus by emerging through the foramen ovale, or it may end in the sphenoparietal sinus or in the cavernous sinus. Besides their meningeal tributaries they receive some small inferior cerebral veins, and communicate with the diploic veins and with the middle cerebral vein.

Wood Jones * has pointed out that the grooves on the inner surfaces of the parietal bones are in reality impressed by the middle meningeal sinuses

* *Journal of Anatomy and Physiology*, vol. xlvi.

and not by the middle meningeal arteries, and says, "contrary to the general belief of surgeons, the vascular tunnel at the pterion, although it lodges arterial branches, is typically formed by, and typically lodges a venous sinus." He finds that the sinuses do not commonly pass out of the skull through the foramen spinosum, but adds that the limited number of his dissections for determining this point does not warrant any dogmatic statement. He is inclined to think that the blood which is poured out in most cases of middle meningeal hæmorrhage may be derived from the easily torn sinuses, and a similar view is expressed in Poirier and Charpy's *Treatise of Human Anatomy*, vol. ii. part 3, p. 930.

The Emissary Veins

The **emissary veins** pass through apertures in the cranial wall and establish communications between the venous sinuses inside the skull and the veins external to it. Some are always present, others occasionally so. 1. A mastoid vein runs through the mastoid foramen and unites the transverse sinus with the posterior auricular or occipital vein. 2. A parietal vein passes through the parietal foramen and connects the superior sagittal sinus with the veins of the scalp. 3. A network of minute veins (rete canalis hypoglossi) traverses the hypoglossal canal and joins the transverse sinus with the internal jugular vein. 4. An inconstant condyloid vein passes through the condyloid canal and connects the transverse sinus with the deep veins of the neck. 5. A network of veins (rete foraminis ovalis) unites the cavernous sinus with the pterygoid plexus through the foramen ovale. 6. Two or three small veins run through the foramen lacerum and connect the cavernous sinus with the pterygoid plexus. 7. A vein traverses the foramen of Vesalius and connects the same parts. 8. An internal carotid plexus of veins accompanies the internal carotid artery through the carotid canal of the temporal bone and unites the cavernous sinus with the internal jugular vein. 9. A vein passes through the foramen cæcum and connects the veins of the nose with the superior sagittal sinus.

Applied Anatomy.—These emissary veins are of importance in surgery. Inflammatory processes commencing on the outside of the skull may travel inwards through them, and lead to thrombosis of the sinuses. To this in former days was to be attributed one of the principal dangers of wounds of the scalp.

By means of these emissary veins blood may be abstracted from the intracranial circulation—e.g. leeches applied behind the ear drain blood from the transverse sinus through the mastoid vein. Again, epistaxis in children may relieve severe headache, the blood which flows from the nose being partly derived from the superior sagittal sinus by means of the vein passing through the foramen cæcum.

THE VEINS OF THE UPPER EXTREMITY AND THORAX

The veins of the upper extremity are divided into two sets, *superficial* and *deep*, which anastomose freely with each other. The superficial veins are placed beneath the skin, in the superficial fascia; the deep veins accompany the arteries. Both sets are provided with valves, which are more numerous in the deep than in the superficial veins.

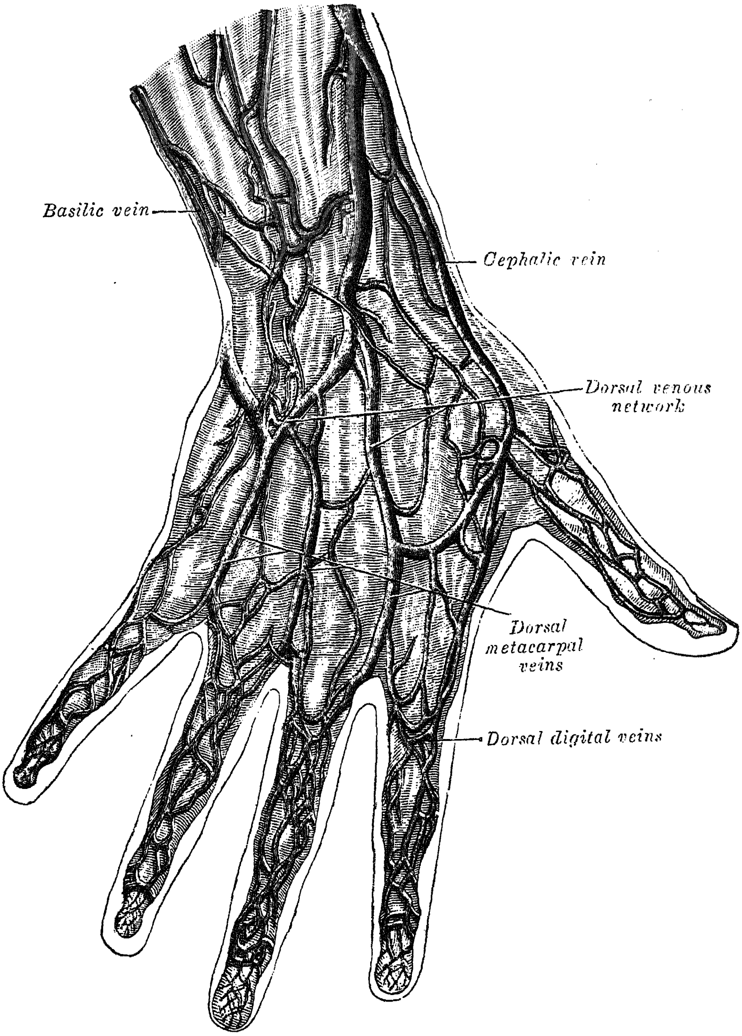
The Superficial Veins of the Upper Extremity (figs. 738, 739)

The **superficial veins** of the upper extremity are the cephalic, basilic, and median antibrachial veins, and their tributaries.

The *dorsal digital veins* pass along the sides of the fingers and are joined to one another by oblique communicating branches. Those from the adjacent sides of the fingers unite to form three *dorsal metacarpal veins* (fig. 738), which end in a *dorsal venous network* opposite the middle of the metacarpus. The radial part of the network is joined by the dorsal digital vein from the radial

side of the index finger and by the dorsal digital veins of the thumb, and is prolonged upwards as the cephalic vein. The ulnar part of the network receives the dorsal digital vein of the ulnar side of the little finger and is continued upwards as the basilic vein. A communicating branch frequently connects the dorsal venous network with the cephalic vein about the middle of the forearm.

Fig. 738.—The veins of the dorsum of the hand. (Bourgery.)

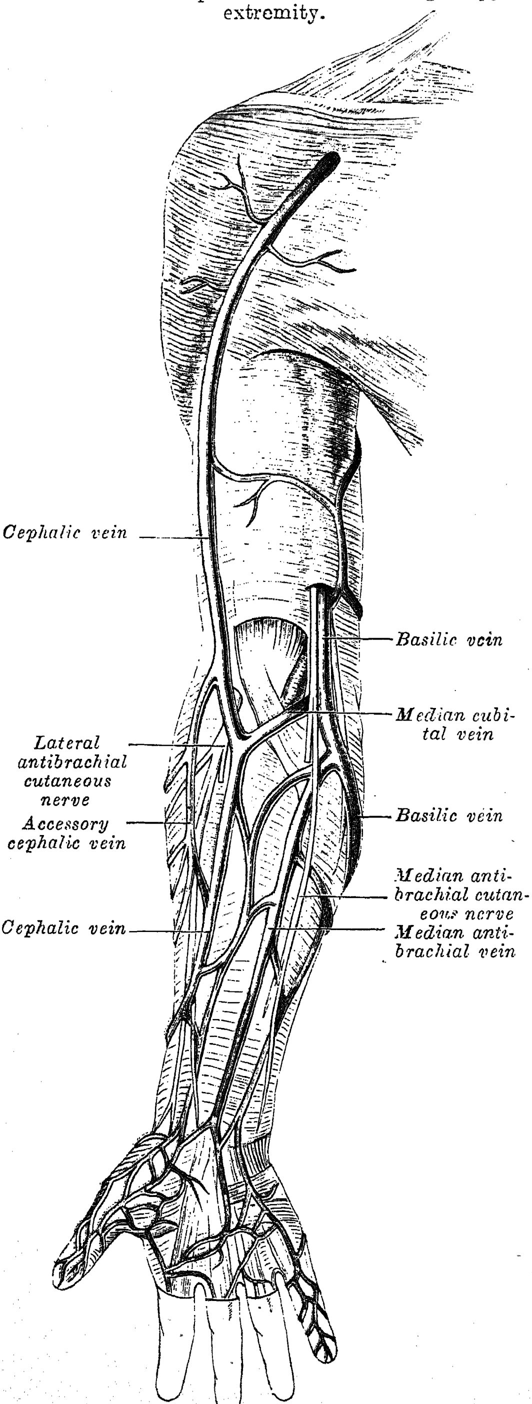


The *proper volar digital veins* are connected to the dorsal digital veins by oblique *intercapitular veins* which pass backwards between the heads of the metacarpal bones. They also drain into a venous plexus which lies superficial to the palmar aponeurosis, and extends over the thenar and hypothenar eminences.

The **cephalic vein** (fig. 739) begins in the radial part of the dorsal venous network of the hand and winds upwards round the radial border of the forearm to its volar surface, receiving tributaries from both surfaces. Below the front of the elbow it gives off the *median cubital vein* (median basilic vein), which receives a communicating branch from the deep veins of the forearm and passes medialwards to join the basilic vein. The cephalic vein then ascends in

front of the elbow in the groove between the Brachioradialis and the Biceps brachii. It crosses superficial to the lateral antibrachial cutaneous nerve and runs upwards along the lateral border of the Biceps brachii. In the upper one-third of the arm it passes between the Pectoralis major and Deltoideus, where it is accompanied by the deltoid branch of the thoraco-acromial artery. It pierces the coracoclavicular fascia, crosses the axillary artery, and ends in the axillary vein just below the clavicle. Sometimes it communicates with the external jugular vein by a branch which ascends in front of the clavicle.

FIG. 739.—The superficial veins of the right upper extremity.



In some cases the median cubital vein is large and carries all or most of the blood from the cephalic into the basilic vein, the result being that the proximal half of the cephalic vein is either absent or of small size.

The *accessory cephalic vein* arises from a small tributary plexus on the back of the forearm or from the ulnar side of the dorsal venous network; it joins the cephalic below the elbow. In some cases it springs from the cephalic vein above the wrist and joins it again higher up. A large oblique branch frequently connects the basilic and cephalic veins on the back of the forearm.

The **basilic vein** (fig. 739) begins in the ulnar part of the dorsal venous network of the hand. It runs up for some distance on the posterior surface of the ulnar side of the forearm but inclines forward to the anterior surface below the elbow. It is joined by the median cubital vein and ascends obliquely in the groove between the Biceps brachii and Pronator teres; filaments of the medial antibrachial cutaneous nerve pass both in front of and behind this portion of the vein. It then runs upwards along the medial border of the Biceps brachii, perforates the deep fascia a little below the middle of the arm, and, ascending on the medial side of the brachial artery to the lower border of the Teres major, is continued onwards as the axillary vein.

The **median antibrachial vein** (fig. 739) drains the venous plexus on the volar surface of the hand. It ascends on the front of the forearm and ends in the basilic vein or the median cubital vein ; in a small proportion of cases it divides below the elbow into two branches, one of which joins the basilic vein, the other the cephalic vein.

Applied Anatomy.—*Venesection* is generally performed at the bend of the elbow, and as a matter of practice the largest vein in this situation, the median cubital (median basilic), is commonly selected.

Intravenous infusion of normal saline solution is frequently required in modern surgery for conditions of severe shock and after profuse hæmorrhages, when suitable donors are not available for transfusion of blood. The patient's arm is surrounded by a tight bandage so as to impede the venous return, and a small incision is made over the largest vein visible in front of the elbow; a double ligature is passed around the vein, and the lower ligature is tied; the vein is then opened and a cannula, connected with a funnel by tubing, is inserted. The bandage is next removed from the arm, and two, three, or more pints of hot saline solution are allowed to flow into the vein; when a sufficient quantity has gone in, the upper ligature round the vein is tied and a stitch put in the skin wound.

The Deep Veins of the Upper Extremity

The **deep veins** follow the course of the arteries, and form their venæ comitantes. They are generally arranged in pairs, and are situated one on either side of the corresponding artery, and connected at intervals by short transverse branches.

The deep veins of the hand.—The superficial and deep volar arterial arches are each accompanied by a pair of venæ comitantes which constitute respectively the *superficial* and *deep volar venous arches*, and receive the veins corresponding to the branches of the arterial arches ; thus the *common volar digital veins*, formed by the union of the *proper volar digital veins*, open into the superficial, and the *volar metacarpal veins* into the deep, volar venous arches. The deep veins accompanying the dorsal metacarpal arteries receive perforating branches from the volar metacarpal veins, and end in the radial veins and in the dorsal venous network.

The **deep veins of the forearm** are the venæ comitantes of the radial and ulnar arteries and constitute respectively the upward continuations of the deep and superficial volar venous arches ; they unite in front of the elbow to form the brachial veins. The radial veins are smaller than the ulnar, and receive the deep veins of the dorsum of the hand. The ulnar veins receive tributaries from the deep volar venous arches and communicate with the superficial veins at the wrist ; near the elbow they receive the volar and dorsal interosseous veins and send a large communicating branch (profunda vein) to the median cubital vein.

The **brachial veins** are placed one on either side of the brachial artery, and receive tributaries corresponding with the branches of that artery ; near the lower margin of the Subscapularis, they join the axillary vein ; the medial one frequently joins the basilic vein.

These deep veins have numerous anastomoses, not only with each other, but also with the superficial veins.

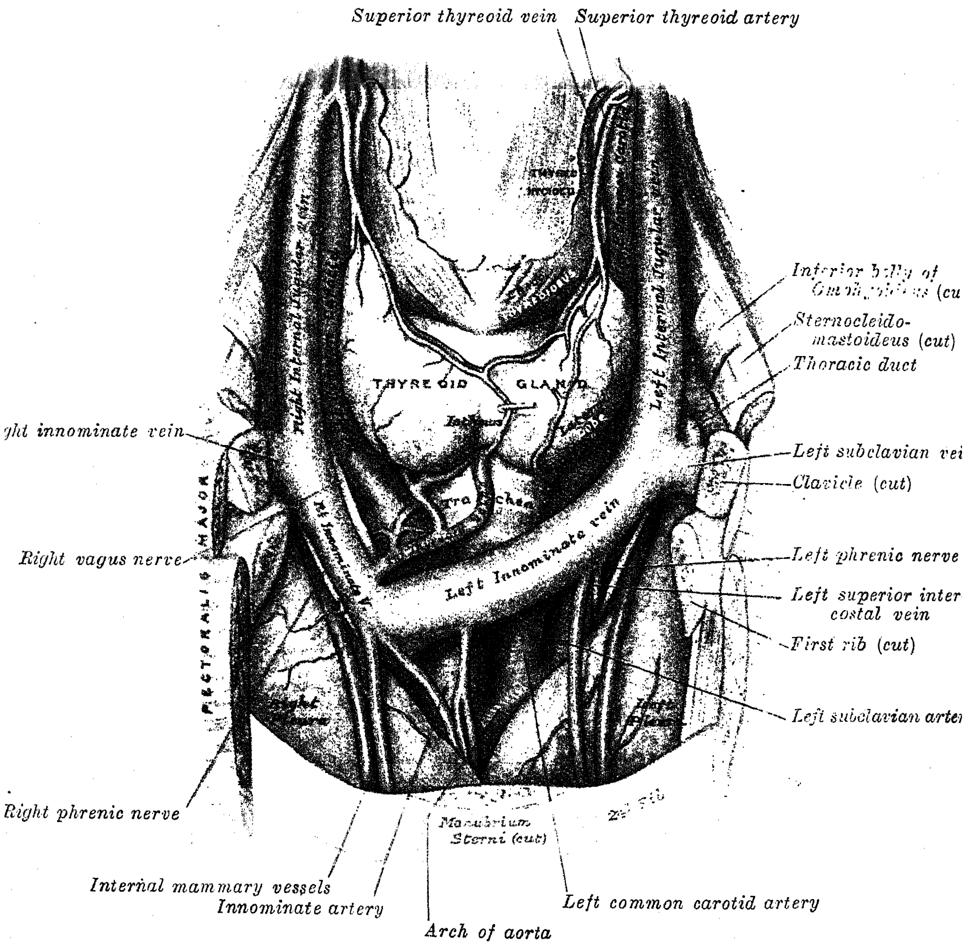
The **axillary vein** begins at the lower border of the Teres major, as the continuation of the basilic vein, increases in size as it ascends, and ends at the outer border of the first rib as the subclavian vein. Near the lower border of the Subscapularis it receives the brachial veins and, close to its termination, the cephalic vein ; its other tributaries correspond with the branches of the axillary artery. It lies on the medial side of the axillary artery, which it partly overlaps ; between the two vessels are the medial anterior thoracic nerve, the medial cord of the brachial plexus, the ulnar nerve and the medial antibrachial cutaneous nerve. It is provided with a pair of valves opposite the lower border of the Subscapularis ; valves are also found at the ends of the cephalic and subscapular veins.

Applied Anatomy.—Since the axillary vein is superficial to and larger than the axillary artery, which it overlaps, it is more liable to be wounded than the artery in the operation of extirpation of the axillary glands, especially as these glands, when diseased,

are apt to become adherent to it. To avoid wounding the vein, it is advisable to expose it as soon as possible; no sharp cutting instruments should be used after the axillary cavity has been freely exposed, and no undue force employed in isolating the glands (p. 643).

The **subclavian vein** (fig. 741), the continuation of the axillary vein, extends from the outer border of the first rib to the medial border of the Scalenus anterior, where it unites with the internal jugular vein to form the innominate

FIG. 740.—Dissection of the lower part of the neck, and the upper part of the thorax. Anterior aspect.



vein. It is in relation, in front, with the clavicle and Subclavius; behind and above, with the subclavian artery, from which it is separated by the Scalenus anterior and the phrenic nerve. Below, it rests in a depression on the first rib and upon the pleura. It is usually provided with a pair of valves, which are situated about 2 cm. from its termination.

Its tributaries are the external jugular vein, sometimes the anterior jugular vein, and occasionally a small branch, which ascends in front of the clavicle, from the cephalic vein.

At its angle of junction with the internal jugular vein, the left subclavian vein receives the thoracic duct, and the right subclavian vein the right lymphatic duct.

The Veins of the Thorax (figs. 740, 741)

The **innominate veins** are two large trunks, placed one on either side of the root of the neck, and formed by the union of the internal jugular and subclavian veins of the corresponding side: they are devoid of valves.

The **right innominate vein** (fig. 740), about 2·5 cm. long, begins behind the sternal end of the right clavicle, and, passing almost vertically downwards, joins the left innominate vein behind the cartilage of the first rib, close to the right border of the sternum, to form the superior vena cava. It lies in front and to the right of the innominate artery and the right vagus nerve. The right pleura, phrenic nerve, and internal mammary artery are posterior to the upper part, and lateral to the lower part of the vein.

Its tributaries are the right vertebral, the right internal mammary and the right inferior thyreoid veins, and sometimes the first right intercostal vein.

The **left innominate vein** (fig. 740), about 6 cm. long, begins behind the sternal end of the left clavicle and runs obliquely downwards and to the right behind the upper half of the manubrium sterni to the sternal end of the first right costal cartilage, where it unites with the right innominate vein to form the superior vena cava. It is separated from the manubrium sterni by the Sternohyoideus and Sternothyreoideus, the thymus or its remains, and some loose areolar tissue. Behind it are the left pleura, the left internal mammary, subclavian and common carotid arteries, the left phrenic and vagus nerves, the trachea and the innominate artery. Below it, is the arch of the aorta.

Its tributaries are the left vertebral, left internal mammary, left inferior thyreoid, and left superior intercostal veins, sometimes the first left intercostal vein and occasionally some thymic and pericardial veins.

Peculiarities.—Sometimes the innominate veins open separately into the right atrium; in such cases the right vein takes the ordinary course of the superior vena cava; the left vein—*left superior vena cava*, as it is then termed—which may communicate by a small branch with the right one, passes in front of the root of the left lung, and, turning to the back of the heart, ends in the right atrium. This occasional condition in the adult is due to the persistence of the early fœtal condition (p. 127), and is the normal state of things in birds and some mammals.

The left innominate vein sometimes projects above the level of the manubrium sterni, crossing the jugular notch, and lying in front of the trachea.

The **internal mammary veins** (fig. 740) are venæ comitantes to the lower half of the internal mammary artery, and receive tributaries corresponding to the branches of the artery. They unite to form a single trunk, which runs up on the medial side of the artery and ends in the corresponding innominate vein. The *superior phrenic vein* (i.e. the vein accompanying the pericardiacophrenic artery) usually opens into the internal mammary vein.

The **inferior thyreoid veins** (figs. 730, 740), two or more in number, arise in the thyreoid gland in a venous network which communicates with the middle and superior thyreoid veins. They form a plexus in front of the trachea. From this plexus a left vein descends and joins the left innominate trunk, and a right vein passes obliquely downwards and to the right across the innominate artery to open into the right innominate vein, at its junction with the superior vena cava; frequently the right and left veins open by a common trunk in the latter situation. These veins receive œsophageal, tracheal, and inferior laryngeal veins, and are provided with valves at their terminations.

The **left superior intercostal vein** (fig. 741) receives the second and third (and sometimes the fourth) left intercostal veins; it runs obliquely upwards and forwards on the left side of the aortic arch between the left phrenic and vagus nerves and opens into the left innominate vein. It usually receives the left bronchial veins, and sometimes the left superior phrenic vein; it communicates below with the accessory hemiazygos vein.

The **superior vena cava** (figs. 653, 654, 655, 657) drains the blood from the upper half of the body. It measures about 7 cm. in length, is formed by the junction of the two innominate veins, and is devoid of valves. It begins behind the cartilage of the right first rib close to the sternum, and, descending vertically behind the first and second intercostal spaces, ends in the upper part of the right atrium opposite the third right costal cartilage; the lower

half of the vessel is within the pericardium. In its course it describes a slight curve, the convexity of which is to the right side.

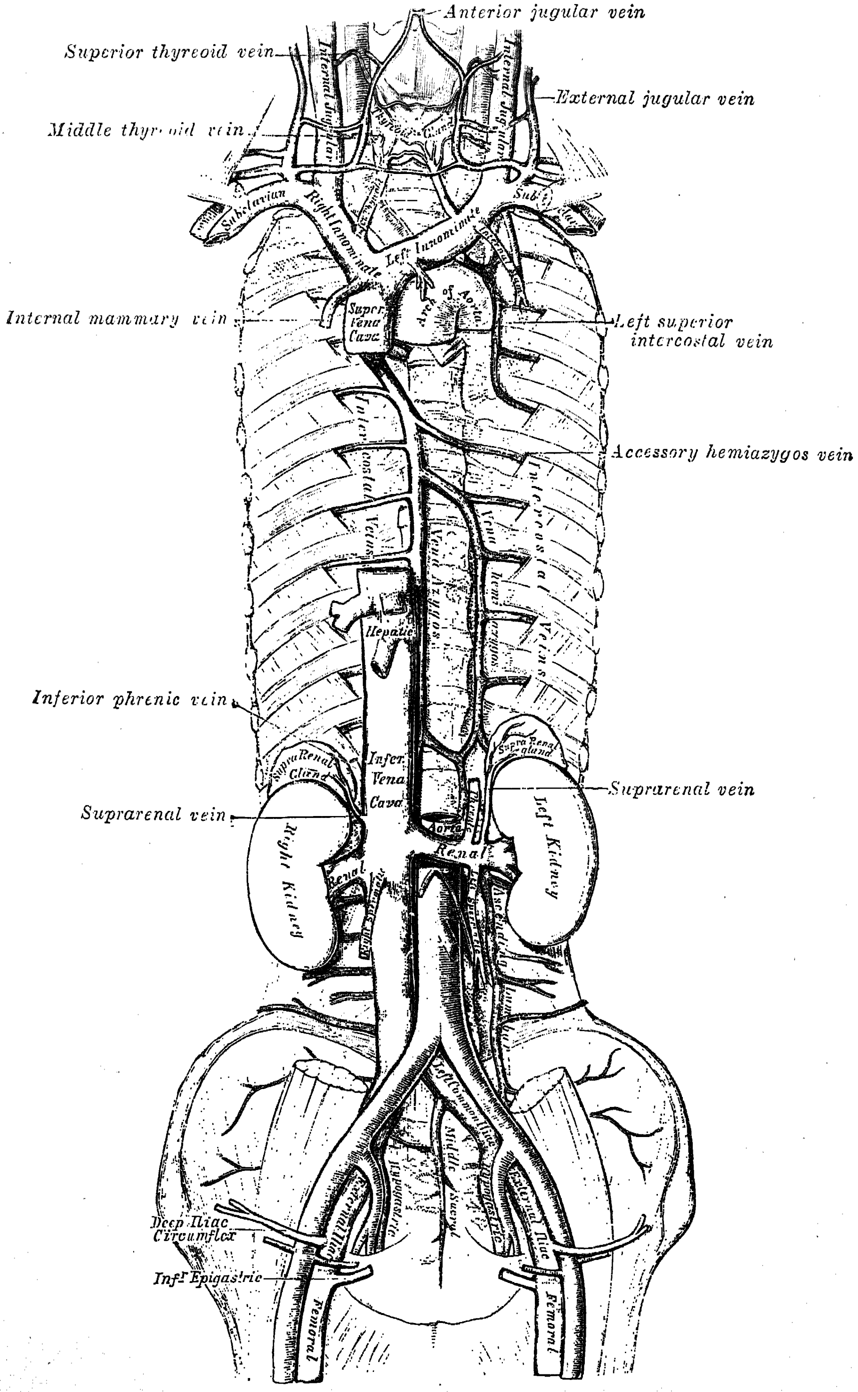


FIG. 741.—The venæ cavæ and the azygos vein, with their tributaries.

Relations.—*In front* of the superior vena cava are the anterior margins of the right lung and pleura with the pericardium intervening below; these separate it

from the first and second intercostal spaces, and from the second and third right costal cartilages; *behind* it are the trachea above, and the root of the right lung below. On its *right side* are the right phrenic nerve and right pleura; on its *left side*, the commencement of the innominate artery and the ascending aorta, the latter overlapping it. The portion contained within the pericardium is covered, in front and laterally, by the serous pericardium.

Tributaries.—Before it pierces the pericardium, the superior vena cava receives the azygos vein and several small veins from the pericardium and other structures in the mediastinal cavity.

The **azygos vein** (fig. 741) begins opposite the first or second lumbar vertebra as a branch of the right ascending lumbar vein (p. 741); sometimes as a branch of the right renal vein, or of the inferior vena cava. It enters the thorax through the aortic hiatus in the Diaphragm, and ascends through the posterior mediastinal cavity to the level of the fourth thoracic vertebra where it arches forward over the root of the right lung, and ends in the superior vena cava, just before that vessel pierces the pericardium. In the *abdomen* it is in front of the upper two lumbar vertebræ, behind the right crus of the Diaphragm, and to the right of the cisterna chyli and the aorta. In the *thorax* it ascends in front of the bodies of the lower eight thoracic vertebræ, the anterior longitudinal ligament, and the right intercostal arteries. On its right side are the right lung and pleura; on its left side, throughout the greater part of its course, are the thoracic duct and aorta, and higher up, where it arches forward above the root of the right lung, the œsophagus, trachea and right vagus.

Tributaries.—It receives the right subcostal vein and the right posterior intercostal veins, with the exception of the vein from the first intercostal space; the veins from the second, third and fourth intercostal spaces open by a common stem called the right superior intercostal vein. It also receives the hemiazygos and accessory hemiazygos veins, several œsophageal, mediastinal, and pericardial veins, and, near its termination, the right bronchial veins. A few imperfect valves are found in the azygos vein; but its tributaries are provided with complete valves.

The **hemiazygos vein** (fig. 741) begins in the left ascending lumbar vein or in the left renal vein. It enters the thorax through the left crus of the Diaphragm, and, ascending on the left side of the vertebral column as high as the eighth thoracic vertebra, passes across the column, behind the aorta, œsophagus, and thoracic duct, to end in the azygos vein. It receives the lower three posterior intercostal veins and the subcostal vein of the left side, and some œsophageal and mediastinal veins.

The **accessory hemiazygos vein** (fig. 694) descends on the left side of the vertebral column. It receives the veins from the fourth (or fifth) to the eighth intercostal spaces inclusive, and sometimes the left bronchial veins. It crosses the body of the seventh thoracic vertebra and joins the azygos vein. The accessory hemiazygos vein sometimes joins the hemiazygos vein, and the common trunk thus formed opens into the azygos vein.

The **intercostal veins** (figs. 694, 741) are sometimes named the *posterior intercostal veins* to distinguish them from the small *anterior intercostal veins* which are tributaries of the musculophrenic and internal mammary veins. They run with the anterior rami of the intercostal arteries and are eleven in number on either side. As they approach the vertebral column each receives a tributary which accompanies the posterior ramus of an intercostal artery, and returns blood from the muscles and skin of the back and from the vertebral venous plexuses.

On both sides of the thorax the first intercostal vein ascends in front of the neck of the first rib and ends in the corresponding innominate or vertebral vein.

On the right side the second, third and fourth posterior intercostal veins unite to form the *right superior intercostal vein*, which joins the terminal part of the azygos vein. The veins from the intercostal spaces below the fourth open separately into the vena azygos.

On the left side the second and third (and sometimes the fourth) posterior intercostal veins unite to form the left superior intercostal vein (p. 729). The veins from the fourth (or fifth) to the eighth intercostal spaces inclusive end in the accessory hemiazygos vein, and the veins from the lower three spaces in the hemiazygos vein.

Applied Anatomy.—In obstruction of the superior vena cava, the azygos and hemiazygos veins are one of the principal means by which the venous circulation is carried on, connecting as they do the superior and inferior venæ cavæ, and communicating with the

the external iliac artery with the lateral femoral circumflex branch of the arteria profunda femoris and the superficial iliac circumflex branch of the femoral artery; and (5) the inferior glutæal branch of the hypogastric artery with the perforating branches of the arteria profunda femoris.

Branches.—The branches of the femoral artery are:

1. Superficial epigastric.
2. Superficial iliac circumflex.
3. Superficial external pudendal.
4. Deep external pudendal.
5. Muscular.
6. Profunda femoris.
7. Highest genicular.

1. The **superficial epigastric artery** (fig. 714) arises from the front of the femoral artery about 1 cm. below the inguinal ligament, and, piercing the femoral sheath and the fascia cribrosa, ascends in front of the inguinal ligament, and between the two layers of the superficial fascia of the abdominal wall nearly as far as the umbilicus. It distributes branches to the superficial subinguinal lymph-glands, the superficial fascia, and the skin; it anastomoses with branches of the inferior epigastric artery, and with its fellow of the opposite side.

2. The **superficial iliac circumflex artery** (fig. 714), the smallest of the superficial branches of the femoral artery, arises close to the preceding vessel, and, piercing the fascia lata, runs lateralwards, parallel with the inguinal ligament, as far as the iliac crest; it gives branches to the skin, superficial fascia, and superficial subinguinal lymph-glands, and anastomoses with the deep iliac circumflex, the superior glutæal and the lateral femoral circumflex arteries.

3. The **superficial external pudendal artery** (fig. 714) arises from the medial side of the femoral artery, close to the preceding vessels, and, after piercing the femoral sheath and fascia cribrosa, courses medialwards, across the spermatic cord (or round ligament of the uterus in the female), to be distributed to the skin on the lower part of the abdomen, the penis and scrotum in the male, and the labium majus in the female, anastomosing with branches of the internal pudendal artery.

4. The **deep external pudendal artery** (fig. 714) passes medialwards across the Pectineus and the Adductor longus; it is covered by the fascia lata, which it pierces at the medial side of the thigh, and is distributed, in the male, to the skin of the scrotum and perinæum, in the female to the labium majus; its branches anastomose with the scrotal (or labial) branches of the perinæal artery.

5. **Muscular branches** are supplied by the femoral artery to the Sartorius, Vastus medialis, and Adductores.

6. The **arteria profunda femoris** (figs. 713, 716) is a large vessel arising from the lateral side of the femoral artery, about 3·5 cm. below the inguinal ligament. At first it lies lateral to the femoral artery; and then runs behind it and the femoral vein to the medial side of the femur; it is continued downwards behind the Adductor longus, and ends at the lower one-third of the thigh in a small branch which pierces the Adductor magnus and anastomoses with the superior muscular branches of the popliteal artery. The terminal part of the profunda is sometimes named the *fourth perforating artery*.

Relations.—*Behind* it, from above downwards, are the Iliacus, Pectineus, Adductor brevis, and Adductor magnus. *In front*, it is separated from the femoral artery by the femoral and profunda veins above, and by the Adductor longus below. *Laterally*, the origin of the Vastus medialis intervenes between it and the femur.

Peculiarities.—This vessel sometimes arises from the medial side, more rarely from the back of the femoral artery. In most cases it arises between 2·25 cm. and 5 cm. below the inguinal ligament; in a few cases the distance is less than 2·25 cm.; more rarely it arises opposite the ligament. Occasionally the distance between the origin of the vessel and the inguinal ligament exceeds 5 cm.

The arteria profunda femoris gives off the following branches:

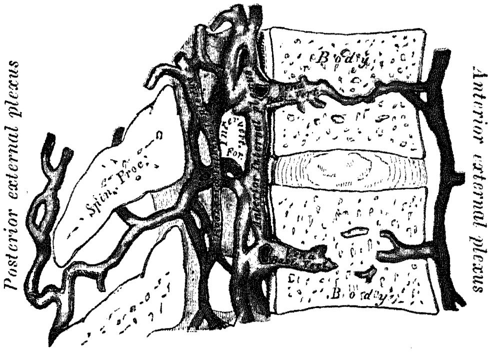
- Lateral femoral circumflex.
- Medial femoral circumflex.
- Perforating.
- Muscular.

The **lateral femoral circumflex artery** (external circumflex artery) (fig. 716) arises from the lateral side of the profunda artery, passes lateralwards between the divisions of the femoral nerve and behind the Sartorius and Rectus femoris, and divides into ascending, transverse, and descending branches.

veins and is connected above with the occipital sinus, the basilar plexus, the condyloid emissary vein, and the rete canalis hypoglossi.

The **basivertebral veins** emerge from the foramina on the posterior surfaces of the vertebral bodies. They are contained in large, tortuous channels in the substance of the bones, similar in every respect to those found in the diploë of the cranial bones. They communicate through small openings on the front and sides of the bodies of the vertebræ with the anterior external vertebral plexuses, and converge behind to form single (sometimes double) veins which open by valved orifices into the transverse branches uniting the anterior internal vertebral plexuses. The basivertebral veins become greatly enlarged in advanced age.

Fig. 743.—A median sagittal section through two thoracic vertebræ, showing the vertebral venous plexuses.



The **intervertebral veins** accompany the spinal nerves through the intervertebral foramina; they receive the veins from the medulla spinalis, drain the internal and external vertebral plexuses and end in the vertebral, intercostal, lumbar, and lateral sacral veins, their orifices being provided with valves.

The **veins of the medulla spinalis** are situated in the pia mater and form a tortuous, venous plexus. In this plexus there are: (1) two median longitudinal veins, one in front of the anterior fissure, and the other behind the posterior sulcus of the medulla spinalis; and (2) four lateral longitudinal veins which run behind the nerve-roots. They end in the internal vertebral venous plexuses. Near the base of the skull they unite to form two or three small trunks, which communicate with the vertebral veins, and end in the inferior cerebellar veins, or in the inferior petrosal sinuses.

THE VEINS OF THE LOWER EXTREMITY, ABDOMEN, AND PELVIS

The veins of the lower extremity are subdivided, like those of the upper extremity, into two sets, *superficial* and *deep*: the superficial veins are placed beneath the skin in the superficial fascia; the deep veins accompany the arteries. Both sets are provided with valves, which are more numerous in the deep than in the superficial set. Valves are more numerous in the veins of the lower than in those of the upper extremity.

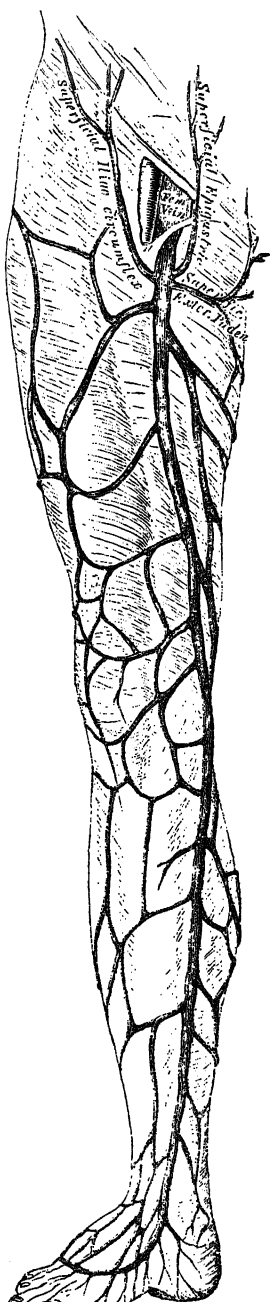
The Superficial Veins of the Lower Extremity

The **superficial veins** of the lower extremity are the great and small saphenous veins and their tributaries.

The *dorsal digital veins* receive, in the clefts between the toes, the *intercapitular veins* from the plantar digital veins, and then join to form *dorsal metatarsal veins*, which unite across the distal ends of the metatarsal bones in a *dorsal venous arch.* Proximal to this arch is an irregular dorsal venous network which receives tributaries from the deep veins and is continuous with the venous network on the front of the leg. At the sides of the foot this network communicates with a *medial* and a *lateral marginal vein*, which are formed mainly by the union of veins from the superficial parts of the sole of the foot.

On the sole of the foot the superficial veins form a *plantar cutaneous venous arch* which extends across the roots of the toes and opens at the sides of the foot into the medial and lateral marginal veins. Proximal to this arch is a *plantar cutaneous venous network* which is especially dense in the fat beneath the heel; this network communicates with the plantar cutaneous venous arch and with the deep veins, but is chiefly drained into the medial and lateral marginal veins.

Fig. 744.—The great saphenous vein and its tributaries.



The **great saphenous vein** (figs. 744, 745), the longest vein in the body, begins in the medial marginal vein of the foot, and ends in the femoral vein about 3 cm. below the inguinal ligament. It ascends in front of the tibial malleolus and along the medial side of the distal one-third of the tibia, and then behind the medial border of the tibia. It runs upwards behind the medial condyles of the tibia and femur and along the medial side of the thigh and, passing through the fossa ovalis, ends in the femoral vein. In the thigh it is accompanied by some branches of the medial femoral cutaneous nerve, at the knee by the saphenous branch of the highest genicular artery, and in the leg and foot by the saphenous nerve which is placed in front of the vein. The great saphenous vein is often duplicated, especially below the knee. The valves in it number from ten to twenty and are more numerous in the leg than in the thigh.

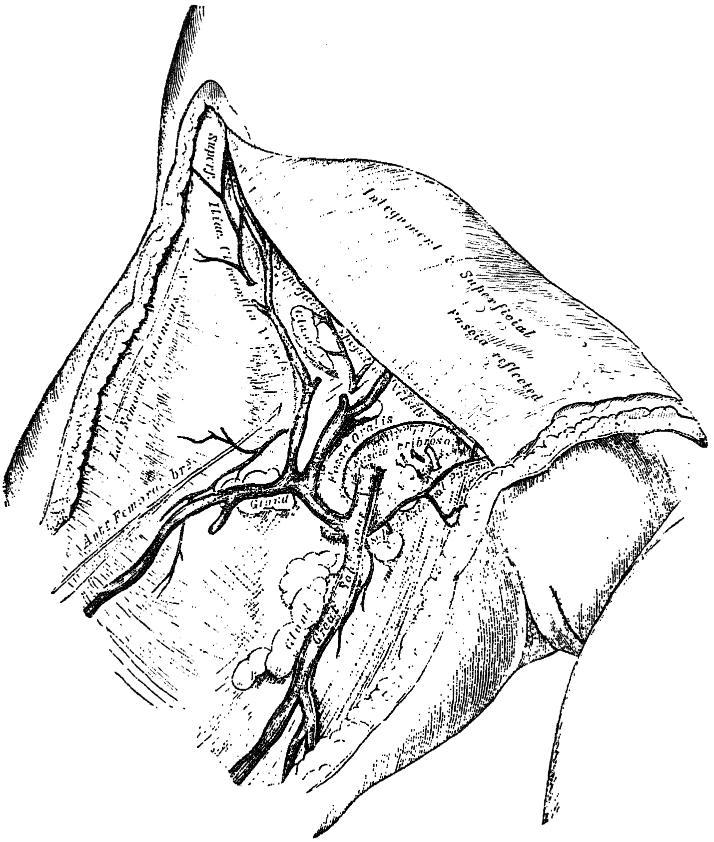
Tributaries.—At the ankle it receives veins from the sole of the foot through the medial marginal vein; in the leg it communicates freely with the small saphenous vein and with the anterior and posterior tibial veins, and receives many cutaneous veins; in the thigh it receives numerous tributaries; those from the medial and posterior parts of the thigh frequently unite to form a large *accessory saphenous vein* which joins the main vein at a variable level. Near the fossa ovalis (fig. 744) it is joined by the superficial epigastric, superficial iliac circumflex, and superficial external pudendal veins. The superficial epigastric and superficial iliac circumflex veins drain the lower part of the abdominal wall, the latter vein also receiving tributaries from the upper and lateral parts of the thigh; the superficial external pudendal vein drains part of the scrotum and receives the superficial dorsal vein of the penis.

A vein, named the *thoraco-epigastric*, runs along the anterolateral wall of the trunk, connecting the superficial epigastric vein, or the femoral vein, with the lateral thoracic veins and establishing an important communication between the femoral and axillary veins.

The **small saphenous vein** (fig. 746) begins behind the lateral malleolus as a continuation of the lateral marginal vein of the foot; it first ascends on the lateral border of the tendo calcaneus, and then along the middle of the back of the leg. It perforates the deep fascia in the lower part of the popliteal

fossa, and ends in the popliteal vein, between the heads of the Gastrocnemius. It communicates with the deep veins on the dorsum of the foot, and receives numerous large tributaries from the back of the leg. Before it pierces the deep fascia, it gives off a branch which runs upwards and medialwards to join the great saphenous vein; this branch is sometimes

FIG. 745.—The great saphenous vein and its tributaries at the fossa ovalis.



large, and may then form the direct continuation of the small saphenous vein. In the lower one-third of the leg the vein is in close relation with the sural nerve, in the upper two-thirds with the medial sural cutaneous nerve.

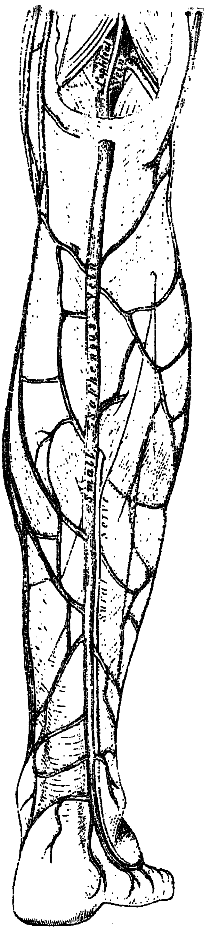
The small saphenous vein possesses from nine to twelve valves, one of which is found near its termination in the popliteal vein.

Applied Anatomy.—A varicose condition is more frequently met with in the saphenous veins than in the other veins of the body, except perhaps the testicular and hæmorrhoidal veins. The main cause of this is the high blood-pressure, determined chiefly by the erect position, and the length of the column of blood, which has to be propelled in an uphill direction. In normal vessels there is only just sufficient force to perform this task; and in those cases where there is diminished resistance of the walls of the veins, these vessels are liable to dilate and a varicose condition is set up. This diminished resistance may be due to heredity, the vein-walls being congenitally weak, or may follow inflammatory conditions of the vessels. Increased blood-pressure in the veins, caused by any obstacle to the return of the venous blood, such as the pressure of a tumour, or the gravid uterus, or tight gartering, may also produce varix. In the normal condition of the veins, the valves in their interior break up the column of blood into a number of smaller columns, and so to a considerable extent mitigate the ill effects of the erect position; but when the dilatation of the veins has reached a certain limit, the valves become incapable of supporting the overlying column of blood, and the pressure is increased, tending to

emphasise also the varicose condition. Both the saphenous veins in the leg are accompanied by nerves, the great saphenous being joined by its companion nerve just below the level of the knee-joint; no doubt much of the pain of varicose veins in the legs is due to this fact.

Operations for the relief of varicose veins are frequently required, portions of the veins being removed after having been ligatured above and below. It is important to note whether the main varicose area drains into the great or the small saphenous vein—the former condition being much the more common—and to control the venous return by removing a small portion of the main trunk just before it opens into the deep vein by passing through the deep fascia; thus in most cases a piece should be removed from the great saphenous before it passes through the fossa ovalis (saphenous opening), leaving sufficient of the vein to form a surface for the attachment of the base of a clot; in addition the affected veins should be excised just above and below the level of the knee-joint. In other cases the small saphenous will have to be dealt with immediately below the point where it pierces the fascial roof of the popliteal fossa.

Fig. 746.—The small saphenous vein.



The Deep Veins of the Lower Extremity

The **deep veins** of the lower extremity accompany the arteries and their branches; they possess numerous valves.

The *plantar digital veins* arise from plexuses on the plantar surfaces of the digits, and, after sending *intercapitular veins* to join the dorsal digital veins, unite to form four *plantar metatarsal veins*; these run backwards in the metatarsal spaces, communicate, by means of perforating veins, with the veins on the dorsum of the foot, and unite to form the *deep plantar venous arch* which lies alongside the plantar arterial arch. From the deep plantar venous arch the *medial* and *lateral plantar veins* run backwards close to the corresponding arteries and, after communicating with the great and small saphenous veins, unite behind the medial malleolus to form the posterior tibial veins.

The **posterior tibial veins** accompany the posterior tibial artery, and are joined by the *peronæal veins*.

The **anterior tibial veins** are the upward continuations of the venæ comitantes of the dorsalis pedis artery. They leave the front of the leg by passing between the tibia and fibula, through the upper part of the crural interosseous membrane, and unite with the posterior tibial veins to form the *popliteal vein*.

The **popliteal vein**, formed by the junction of the anterior and posterior tibial veins at the lower border of the Popliteus, ascends through the popliteal fossa to the aperture in the Adductor magnus, where it becomes the femoral vein. In the lower part of its course it is medial to the popliteal artery; between the heads of the Gastrocnemius it is superficial to it; above the knee-joint, it is posterolateral to it. Its tributaries are the small saphenous vein and the veins corresponding to the branches of the popliteal artery. There are usually four valves in the popliteal vein.

The **femoral vein** accompanies the femoral artery, beginning at the opening in the Adductor magnus, as a continuation of the popliteal vein, and ending at the level of the inguinal ligament, by becoming the external iliac vein. In the lower part of the adductor canal it is posterolateral to the femoral artery; in the upper part of the canal, and in the lower part of the femoral triangle, it is behind the artery. At the base of the femoral triangle it is medial to the artery (figs. 710, 711); here it occupies the middle compartment of the femoral sheath, and is placed between the femoral artery and the femoral canal. It receives numerous muscular tributaries, and about 4 cm. below the inguinal ligament is joined by the vena profunda femoris, and a little higher by the great saphenous vein. It contains three valves.

The *vena profunda femoris* lies superficial to the arteria profunda femoris artery; it receives tributaries corresponding to the muscular and perforating branches of that artery, and through these establishes communications with the popliteal vein below and the inferior glutæal vein above. It also receives the medial and lateral femoral circumflex veins.

The Veins of the Abdomen and Pelvis (fig. 747)

The **external iliac vein**, the upward continuation of the femoral vein, begins behind the inguinal ligament, and ascends along the brim of the lesser pelvis, to a point opposite the sacro-iliac articulation, where it unites with the hypogastric vein to form the common iliac vein. On the right side, it lies at first medial to the artery; but, as it passes upwards, gradually inclines behind it. On the left side, it lies altogether on the medial side of the artery. It frequently contains one, sometimes two, valves.

Tributaries.—It receives the inferior epigastric, deep iliac circumflex, and pubic veins.

The **inferior epigastric vein** is formed by the union of the venæ comitantes of the inferior epigastric artery, which communicate above with the superior epigastric vein; it joins the external iliac vein about 1 cm. above the inguinal ligament.

The **deep iliac circumflex vein** is formed by the union of the venæ comitantes of the deep iliac circumflex artery, and joins the external iliac vein about 2 cm. above the inguinal ligament.

The **pubic vein** communicates with the obturator vein in the obturator foramen, ascends on the pelvic surface of the os pubis alongside the pubic branch of the inferior epigastric artery and ends in the external iliac vein.

The **hypogastric or internal iliac vein** begins near the upper part of the greater sciatic foramen, ascends behind and slightly medial to the hypogastric artery, and, at the brim of the pelvis, joins with the external iliac vein to form the common iliac vein.

Tributaries.—With the exception of the fœtal umbilical vein, which passes upwards and backwards from the umbilicus to the liver, and the iliolumbar vein, which usually joins the common iliac vein, the tributaries of the hypogastric vein correspond with the branches of the hypogastric artery. It receives (*a*) the glutæal, internal pudendal, and obturator veins, which have their origins outside the pelvis; (*b*) the lateral sacral veins, which lie in front of the sacrum; and (*c*) the middle hæmorrhoidal, the vesical, uterine, and vaginal veins, which originate in venous plexuses connected with the pelvic viscera.

1. The **superior glutæal veins** (glutæal veins) are the venæ comitantes of the superior glutæal artery; they receive tributaries from the buttock corresponding with the branches of the artery, enter the pelvis through the greater sciatic foramen, above the Piriformis, and end in the hypogastric vein; they frequently unite to form a single trunk before ending in this vein.

2. The **inferior glutæal veins** (sciatic veins) are the venæ comitantes of the inferior glutæal artery; they begin on the upper part of the back of the thigh, where they anastomose with the medial femoral circumflex and first perforating veins; they enter the pelvis through the lower part of the greater sciatic foramen and join to form a stem which opens into the lower part of the hypogastric vein.

3. The **internal pudendal veins** (internal pudic veins) are the venæ comitantes of the internal pudendal artery. They begin in the pudendal plexus, accompany the internal pudendal artery, and unite to form a single vessel, which ends in the hypogastric vein. They receive the veins from the urethral bulb, and the perinæal and inferior hæmorrhoidal veins. The deep dorsal vein of the penis and the dorsal vein of the clitoris communicate with the internal pudendal veins, but end mainly in the pudendal plexus.

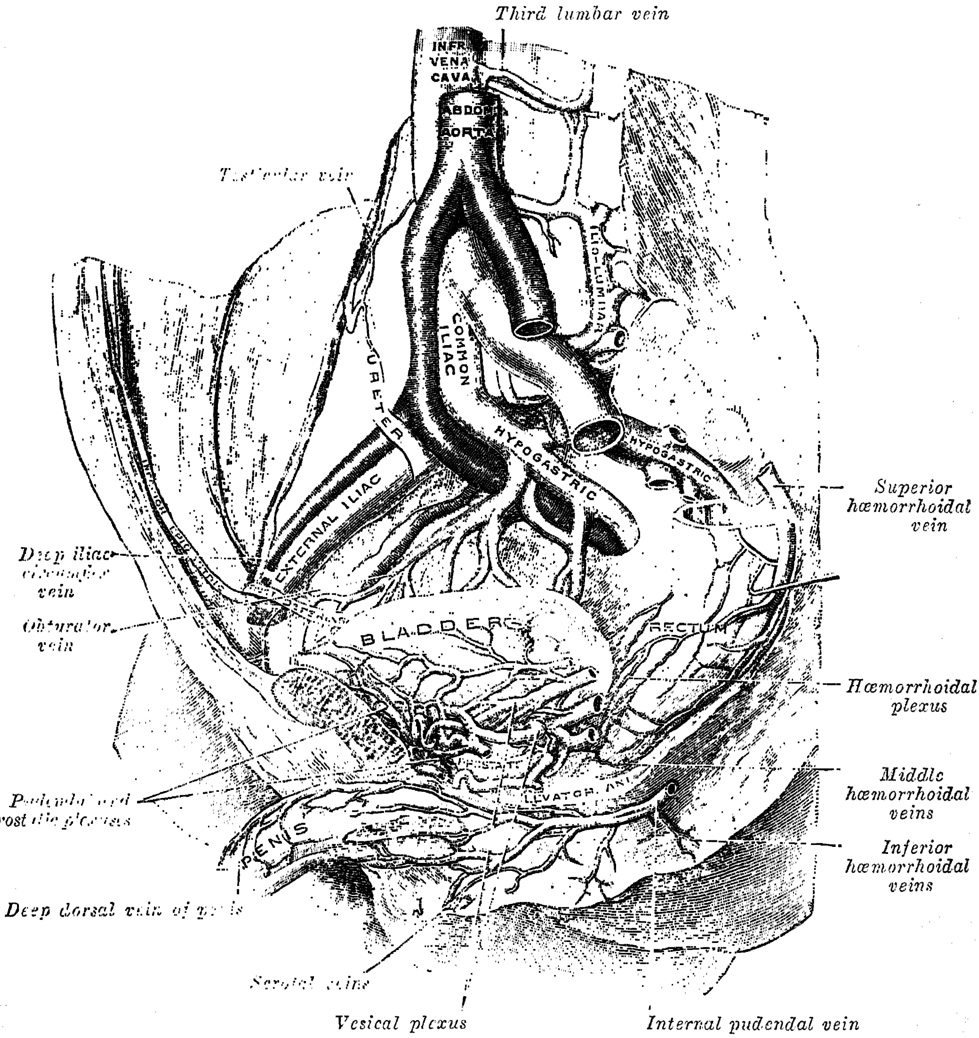
4. The **obturator vein** begins in the upper portion of the adductor region of the thigh, and enters the pelvis through the upper part of the obturator foramen. It runs backwards and upwards on the lateral wall of the pelvis below the obturator artery and lateral to the peritoneum; it passes between the ureter and the hypogastric artery, and ends in the hypogastric vein. Sometimes it is replaced by an enlarged pubic vein which joins the external iliac vein.

5. The **lateral sacral veins** accompany the lateral sacral arteries and end in the hypogastric vein.

6. The **middle hæmorrhoidal vein** varies in size; it begins in the hæmorrhoidal plexus and receives tributaries from the bladder, prostate, and seminal vesicle; it runs lateralwards on the pelvic surface of the Levator ani and ends in the hypogastric vein.

The hæmorrhoidal plexus surrounds the rectum, and communicates in front with the vesical plexus in the male, and the uterovaginal plexus in the

FIG. 747.—The veins of the right half of the male pelvis. (Spalteholz.)



female. It consists of two parts, an *internal* in the submucosa, and an *external* outside the muscular coat of the rectum. The internal plexus presents a series of dilated pouches which are arranged in a circle around the tube, immediately above the anal orifice, and are connected by transverse branches; it drains mainly into the superior hæmorrhoidal vein. The lower part of the external plexus is drained by the inferior hæmorrhoidal veins into the internal pudendal vein; the middle part by the middle hæmorrhoidal vein into the hypogastric vein; and the upper part by the superior hæmorrhoidal vein which forms the commencement of the inferior mesenteric vein, a tributary of the portal vein. A free communication between the portal and systemic venous systems is established through the hæmorrhoidal plexus.

The pudendal plexus lies behind the arcuate pubic ligament and the lower part of the symphysis pubis, and in front of the bladder and prostate.

Its chief tributary is the deep dorsal vein of the penis, but it also receives branches from the front of the bladder and prostate. It communicates with the vesical plexus and with the internal pudendal vein, and drains into the vesical and hypogastric veins. The *prostatic veins* form a well-marked *prostatic plexus* which lies partly in the fascial sheath of the prostate and partly between the sheath and the prostatic capsule; it communicates with the pudendal and vesical plexuses.

The **vesical plexus** envelops the lower part of the bladder and, in the male, the base of the prostate. It communicates with the pudendal plexus and in the male with the prostatic plexus, and in the female with the vaginal plexus. It is drained, by means of several vesical veins, into the hypogastric veins.

Applied Anatomy.—The veins of the hæmorrhoidal plexus are apt to become dilated and varicose, and form piles. This is due to several anatomical reasons: the vessels are contained in very loose connective tissue, so that they get less support from surrounding structures than most other veins, and are less capable of resisting increased blood-pressure; the condition is favoured by the fact that the superior hæmorrhoidal and portal veins have no valves; the veins pass through muscular tissue and are liable to be compressed by its contraction, especially during the act of defæcation; they are affected by every form of portal obstruction.

The prostatic plexus of veins is apt to become congested in inflammatory conditions in the neighbourhood such as acute gonorrhœal prostatitis. It is owing to the free communication which exists between this and the middle hæmorrhoidal plexus that great relief can be given by free saline purgation. Hæmorrhage may be very free from the prostatic plexus after operations on that gland, but can usually be checked by hot fluid irrigation.

The **dorsal veins of the penis** are two in number, a superficial and a deep. The *superficial dorsal vein* drains the prepuce and skin of the penis, and, running backwards in the subcutaneous tissue, inclines to the right or left, and opens into the corresponding superficial external pudendal vein, a tributary of the great saphenous vein. The *deep dorsal vein* lies within the fibrous envelope of the penis; it receives blood from the glans penis and corpora cavernosa penis, and courses backwards in the middle line between the dorsal arteries; near the root of the penis it passes between the two parts of the suspensory ligament and then through an aperture between the arcuate pubic ligament and the transverse ligament of the pelvis, and divides into two branches, which enter the pudendal plexus. It also communicates below the symphysis pubis with the internal pudendal vein. The *dorsal vein of the clitoris*, after a similar course to that of the deep dorsal vein of the penis, ends in the pudendal plexus.

The **uterine plexuses** lie along the sides and superior angles of the uterus between the two layers of the broad ligament, and communicate with the ovarian and vaginal plexuses. They are drained by a pair of uterine veins on either side; these arise from the lower parts of the plexuses, opposite the external orifice of the uterus, and open into the corresponding hypogastric vein.

The **vaginal plexuses** are placed at the sides of the vagina; they communicate with the uterine, vesical, and hæmorrhoidal plexuses, and are drained by the vaginal veins, one on either side, into the hypogastric veins.

The **common iliac veins** (fig. 747) are formed by the union of the external iliac and hypogastric veins, in front of the sacro-iliac articulation; passing obliquely upwards they end on the right side of the fifth lumbar vertebra by uniting with each other at an acute angle to form the inferior vena cava. The *right common iliac vein*, shorter than the left, is nearly vertical in its direction, and ascends behind, and then lateral to its artery. The *left common iliac vein*, longer and more oblique than the right, is at first situated on the medial side of its artery, and then behind the right common iliac artery. Each common iliac vein receives the iliolumbar, and sometimes the lateral sacral veins; the left vein receives the middle sacral vein. There are no valves in these veins.

The **middle sacral veins** accompany the corresponding artery along the front of the sacrum, and join to form a single vein, which usually ends in the left common iliac vein, but sometimes in the angle of junction of the two common iliac veins.

Peculiarities.—The left common iliac vein, instead of joining with the right in its usual position, occasionally ascends on the left side of the aorta as high as the kidney, where, after receiving the left renal vein, it crosses the aorta, and joins the right vein to form the vena cava.

The **inferior vena cava** (figs. 695, 741) conveys the blood from the parts below the Diaphragm to the right atrium of the heart. It is formed by the junction of the two common iliac veins, in front of the body of the fifth lumbar vertebra, a little to the right of the middle line. It ascends in front of the vertebral column, on the right side of the aorta, and, having reached the liver, is contained in a deep groove on its posterior surface—a groove which is occasionally converted into a tunnel by a band of liver substance. It then perforates the Diaphragm between the median and right portions of its central tendon; it subsequently inclines forwards and medialwards for about 2 cm., and, piercing the fibrous pericardium, passes behind the serous pericardium to open into the lower and posterior part of the right atrium. In front and to the left of its atrial orifice is a semilunar valve, termed the *valve of the inferior vena cava* (Eustachian valve); this valve is rudimentary in the adult, but is of large size and exercises an important function in the fœtus (p. 594). The trunk of the inferior vena cava is devoid of valves.

Relations.—The *abdominal portion* of the inferior vena cava is in relation *in front* with the right common iliac artery, the lower part of the mesentery and its vessels, the right testicular artery, the inferior part of the duodenum, the head of the pancreas, the portal vein, the superior portion of the duodenum, the epiploic foramen, and the posterior surface of the liver; *behind*, with the bodies of the lower lumbar vertebræ and the anterior longitudinal ligament, the right Psoas major, the right crus of the Diaphragm, the right inferior phrenic, suprarenal, renal and lumbar arteries, right sympathetic trunk and right cœliac ganglion, and the medial part of the right suprarenal gland; on the *right side*, with the right kidney and ureter; on the *left side*, with the aorta, right crus of the Diaphragm, and the caudate lobe of the liver.

The *thoracic portion* is only about 2 cm. in length, and is situated partly inside and partly outside the pericardial sac. The *extrapericardial part* is separated from the right pleura and lung by a fibrous band, named the *right phrenicopericardiac ligament.* This ligament, often feebly marked, is attached below to the margin of the vena-caval opening in the Diaphragm and above to the pericardium in front of the root of the right lung. The *intrapericardiac part* is very short and is covered on the front and sides by the serous layer of the pericardium.

Peculiarities.—This vessel is sometimes placed on the left side of the aorta, as high as the left renal vein, and, after receiving this vein, crosses over to its usual position on the right side; or it may be placed altogether on the left side of the aorta, and in such a case the abdominal and the thoracic viscera, together with the great vessels, are all transposed. Occasionally it joins the azygos vein, which is then of large size. In such cases, the superior vena cava receives the whole of the blood from the body, except that from the hepatic veins, which passes directly into the right atrium.

Applied Anatomy.—Thrombosis of the inferior vena cava is due to much the same causes as that of the superior (p. 732). It usually causes œdema of the legs and back, without ascites; if the renal veins are involved, blood and albumin will often appear in the urine. An extensive collateral venous circulation is soon established by enlargement either of the superficial or of the deep veins, or of both. In the first case the epigastric, the iliac circumflex, the lateral thoracic, the internal mammary, the intercostals, the external pudendal, and the lumbovertebral anastomotic veins of Braune effect the communication with the superior cava; in the second, the deep anastomosis is made by the azygos and hemiazygos and the lumbar veins.*

Tributaries.—In addition to the two common iliac veins the inferior vena cava receives the following veins:

Lumbar.	Renal.	Right inferior phrenic.
Right testicular or ovarian.	Right suprarenal.	Hepatic.

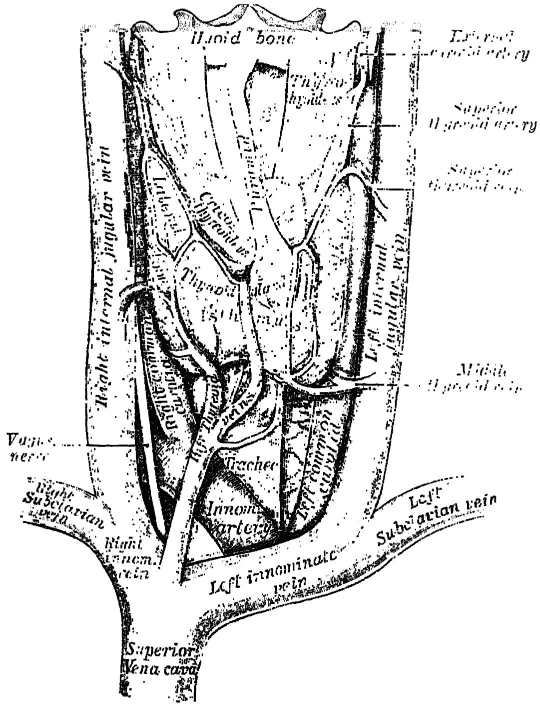
The **lumbar veins**, four in number on either side, collect the blood by dorsal tributaries from the muscles and skin of the loins, and by abdominal tributaries from the walls of the abdomen, where they communicate with the epigastric veins. At the vertebral column, they receive veins from the vertebral plexuses, and then pass forwards on the sides of the bodies of the vertebræ, beneath the Psoas major, and end in the posterior part of the inferior vena cava. The left lumbar veins are longer than the right, and run behind the aorta. The lumbar veins are connected together by a longitudinal vein which passes in

* G. Blumer, in Osler and McCrae's *System of Medicine*, London, 1908, vol. iv.

superficial or deep to the vein. The deep cervical glands lie along the course of the vein, mainly on its superficial aspect. At the root of the neck the right internal jugular vein is placed at a little distance from the common carotid artery, and crosses the first part of the subclavian artery, while the left internal jugular vein usually overlaps the common carotid artery.

Tributaries.—The internal jugular vein receives the inferior petrosal sinus, the common facial, lingual, pharyngeal, superior and middle thyreoid veins, and sometimes the occipital vein. The thoracic duct opens into the angle of union of the left subclavian and internal jugular veins, and the right lymphatic duct into the angle of union of the right subclavian and internal jugular veins.

Fig. 730.—The veins of the thyreoid gland.



The **inferior petrosal sinus** leaves the skull through the anterior part of the jugular foramen, and joins the superior bulb of the internal jugular vein.

The **lingual veins** begin on the dorsum, sides, and under surface of the tongue, and, passing backwards along the course of the lingual artery, end in the internal jugular vein. The **vena comitans hypoglossi** (ranine vein), a branch of considerable size, begins below the tip of the tongue, and may join the lingual veins; generally, however, it passes backwards superficial to the Hyoglossus, and opens into the common facial vein.

The **pharyngeal veins** begin in the *pharyngeal plexus* on the outer surface of the pharynx, and, after receiving some posterior meningeal veins and the vein of the pterygoid canal, end in the internal jugular vein. They occasionally open into the facial, the lingual, or the superior thyreoid vein.

The **superior thyreoid vein** (fig. 730) begins in the substance and on the surface of the thyreoid gland, by tributaries corresponding with the branches of the superior thyreoid artery. It accompanies this artery, receives the superior laryngeal and cricothyreoid veins, and ends in the internal jugular vein.

The **middle thyreoid vein** (fig. 730) collects the blood from the lower part of the thyreoid gland, receives some veins from the larynx and trachea, and ends in the lower part of the internal jugular vein.

The inferior thyreoid veins are described on p. 729.

The **common facial** and **occipital veins** have been described (pp. 710, 712).

Applied Anatomy.—The internal jugular vein requires ligature in cases of septic thrombosis of the transverse sinus, secondary to suppurative otitis media, in order to prevent septic emboli being carried into the general circulation. This operation has been performed in many cases, with the most satisfactory results. The cases are generally those of chronic disease of the middle ear, with discharge of pus which perhaps has existed for many years. Such cases are always extremely grave, for there is a danger of portions of the thrombus or clot being detached and causing septic embolism in the lungs. If the condition be suspected, the diseased bone should be removed at once from the mastoid process. The sinus is then investigated, and if it be found thrombosed, the surgeon should proceed to ligature the internal jugular vein, through an incision along the anterior border of the Sternocleidomastoideus, the centre of the incision being on a

lies in the groove on the posterior surface of the liver. The hepatic veins are arranged in two groups, upper and lower. The *upper group* usually consists of three large veins, right, left and middle, the last emerging from the caudate lobe; those of the *lower group* vary in number; they are of small size and come from the right and caudate lobes. The hepatic veins are in direct contact with the hepatic tissue and are destitute of valves.

The Portal System of Veins (fig. 748)

The portal system includes all the veins which drain the blood from the abdominal part of the digestive tube (with the exception of the lower part of the rectum) and from the spleen, pancreas, and gall-bladder. From these viscera the blood is conveyed to the liver by the *portal vein*. In the liver this vein ramifies like an artery and ends in capillary-like vessels termed sinusoids, from which the blood is conveyed to the inferior vena cava by the hepatic veins. The blood of the portal system therefore passes through two sets of minute vessels, viz. (*a*) the capillaries of the digestive tube, spleen, pancreas, and gall bladder; and (*b*) the sinusoids of the liver. In the adult the portal vein and its tributaries are destitute of valves; in the fœtus and for a short time after birth valves can be demonstrated in the tributaries of the portal vein; as a rule they atrophy and disappear, but sometimes persist in a degenerate form.

The **portal vein** is about 8 cm. long, and is formed at the level of the second lumbar vertebra by the junction of the superior mesenteric and lienal (splenic) veins, the union of these veins taking place in front of the inferior vena cava and behind the neck of the pancreas. It passes upwards behind the superior part of the duodenum, and then ascends in the right border of the lesser omentum to the right extremity of the porta hepatis (transverse fissure of the liver), where it divides into a right and a left branch, which accompany the corresponding branches of the hepatic artery into the substance of the liver. In the lesser omentum it is placed behind and between the bile-duct and the hepatic artery, the former lying to the right of the latter; it is surrounded by the hepatic plexus of nerves, and is accompanied by numerous lymphatic vessels and some lymph-glands. The *right branch* of the portal vein enters the right lobe of the liver, but before doing so generally receives the cystic vein. The *left branch*, longer but of smaller calibre than the right, gives branches to the caudate and quadrate lobes, crosses the left sagittal fossa (longitudinal fissure), and then enters the left lobe of the liver. As it crosses the left sagittal fossa it is joined in front by the para-umbilical veins (p. 744) and by a fibrous cord, the *ligamentum teres* or *obliterated umbilical vein*, and is united behind to the inferior vena cava by a second fibrous cord, the *ligamentum venosum* or *obliterated ductus venosus*.

The tributaries of the portal vein are:

1. Lienal (Splenic).
2. Superior mesenteric.
3. Coronary.
4. Right gastric.
5. Cystic.
6. Para-umbilical.

1. The **lienal or splenic vein** (fig. 748) is of large size, but is not tortuous like the artery; it commences by five or six branches which return the blood from the spleen. These unite to form a single vessel, which passes from left to right, grooving the upper part of the posterior surface of the pancreas, below the lienal artery, and ends behind the neck of the pancreas by uniting at a right angle with the superior mesenteric vein, to form the portal vein.

Tributaries.—It receives the short gastric veins, the left gastro-epiploic vein, the pancreatic veins, and the inferior mesenteric vein.

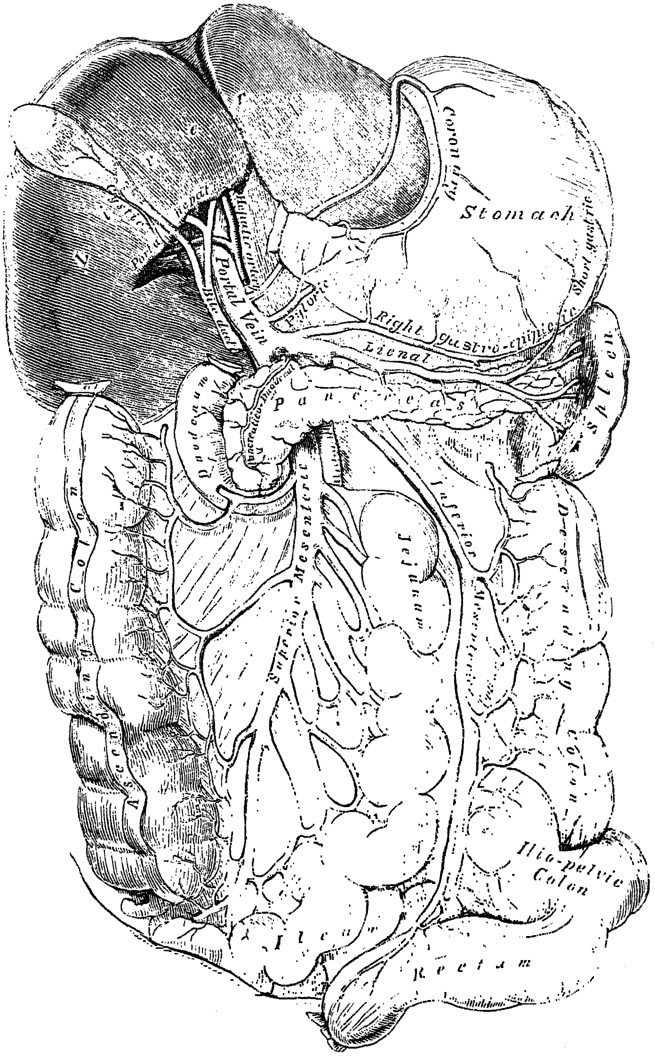
(*a*) The **short gastric veins**, four or five in number, drain the fundus and left part of the greater curvature of the stomach, and pass between the two layers of the gastrolienal ligament to end in the lienal vein or in one of its large tributaries.

(*b*) The **left gastro-epiploic vein** receives branches from the surfaces of the stomach and from the greater omentum; it runs from right to left along the greater curvature of the stomach and ends in the commencement of the lienal vein.

(*c*) The **pancreatic veins** are several small vessels which drain the body and tail of the pancreas.

(*d*) The **inferior mesenteric vein** returns blood from the rectum, and from the sigmoid and descending parts of the colon. It begins in the rectum as the *superior hæmorrhoidal vein*, which has its origin in the hæmorrhoidal plexus (p. **738**), and through this plexus communicates with the middle and inferior hæmorrhoidal veins. The superior hæmorrhoidal vein leaves the lesser pelvis, crosses the left common iliac vessels with the superior hæmorrhoidal artery, and is continued

FIG. 748.—The portal vein and its tributaries.



upwards as the inferior mesenteric vein. This vein lies to the left of its artery and ascends behind the peritoneum and in front of the left Psoas major; it then passes behind the body of the pancreas and opens into the lienal vein; sometimes it ends in the angle of union of the lienal and superior mesenteric veins.

If a superior duodenal fossa be present the inferior mesenteric vein frequently lies between the layers of the fold of peritoneum (superior duodenal fold) which forms the anterior wall of the fossa.

Tributaries.—The inferior mesenteric vein receives the sigmoid veins from the sigmoid colon, and the left colic vein from the descending colon and left colic flexure.

2. The **superior mesenteric vein** (fig. 748) returns the blood from the small intestine, from the cæcum, and from the ascending and transverse portions

of the colon. It begins in the right iliac fossa by the union of the veins which drain the terminal part of the ileum, the cæcum and vermiform process. It ascends between the two layers of the mesentery on the right side of the superior mesenteric artery, and in its upward course passes in front of the right ureter, the inferior vena cava, the horizontal part of the duodenum, and the processus uncinatus of the head of the pancreas. Behind the neck of the pancreas it unites with the lienal vein to form the portal vein.

Tributaries.—The superior mesenteric vein receives the veins which correspond with the branches of the superior mesenteric artery, viz. the jejunal, ileal, ileocolic, right colic, and middle colic veins; it is also joined by the right gastro-epiploic and the pancreaticoduodenal veins.

The **right gastro-epiploic vein** receives branches from the greater omentum and from the lower part of the stomach; it runs from left to right along the greater curvature of the stomach, between the two layers of the greater omentum.

The **pancreaticoduodenal veins** accompany their corresponding arteries; the lower one frequently joins the right gastro-epiploic vein.

3. The **coronary vein** derives tributaries from both surfaces of the stomach; it runs from right to left along the lesser curvature of the stomach between the two layers of the lesser omentum, to the œsophageal opening of the stomach, where it receives some œsophageal veins. It then turns backwards and passes from left to right behind the omental bursa, and ends in the portal vein.

4. The **right gastric vein** (pyloric vein), of small size, runs from left to right along the pyloric portion of the lesser curvature of the stomach between the two layers of the lesser omentum, and ends in the portal vein.

5. The **cystic vein** drains the blood from the gall-bladder; it accompanies the cystic duct, and usually ends in the right branch of the portal vein.

6. **Para-umbilical veins.**—In the course of the ligamentum teres of the liver and of the middle umbilical ligament, small veins (para-umbilical) are found, which establish an anastomosis between the veins of the anterior abdominal wall and the portal, hypogastric, and iliac veins. The best marked of these small veins is one which begins at the umbilicus and runs backwards and upwards in, or on the surface of, the ligamentum teres between the layers of the falciform ligament, to end in the left branch of the portal vein.

Applied Anatomy.—Obstruction to the portal vein may produce ascites, and this may arise from many causes, e.g. (1) the pressure of a tumour on the portal vein, such as cancer or hydatid cyst in the liver, enlarged lymph-glands in the lesser omentum, or cancer of the head of the pancreas; (2) from cirrhosis of the liver, when the radicles of the portal vein are pressed upon by the contracting fibrous tissue in the portal canals; (3) from valvular disease of the heart, and back pressure on the hepatic veins, and so on the whole of the circulation through the liver. In this condition the prognosis as regards life and freedom from ascites may be much improved by the establishment of a good collateral circulation between the portal and systemic veins. This is effected by communications between (*a*) the gastric veins, and the œsophageal veins which often project as a varicose bunch into the stomach, emptying themselves into the hemiazygos vein; (*b*) the veins of the colon and duodenum, and the left renal vein; (*c*) the accessory portal system of Sappey, branches of which pass in the round and falciform ligaments (particularly the latter) to unite with the epigastric and internal mammary veins, and through the diaphragmatic veins with the azygos; a single large vein, shown to be a para-umbilical vein, may pass from the hilum of the liver by the round ligament to the umbilicus, producing there a bunch of prominent varicose veins known as the *caput Medusæ*; (*d*) the veins of Retzius, which connect the intestinal veins with the inferior vena cava and its retroperitoneal branches; (*e*) the superior, middle and inferior hæmorrhoidal; (*f*) very rarely the ductus venosus remains patent, affording a direct connexion between the portal vein and the inferior vena cava.

An operation for the relief of portal obstruction by increasing the number of venous communications has been advocated by Rutherford Morison and by Talma. It consists in roughening the opposed surfaces of the liver and Diaphragm and stitching them together, so as to secure vascular inflammatory adhesions between the two. The greater omentum may with advantage be interposed between them, so as to increase the amount of the adhesions.

Thrombosis of the portal vein is a very serious event, and is oftenest due to pathological processes causing compression of the vessel or injury to its wall, such as tumours or inflammation about the pylorus or head of the pancreas, or to gall-stones, or cirrhosis of the liver.

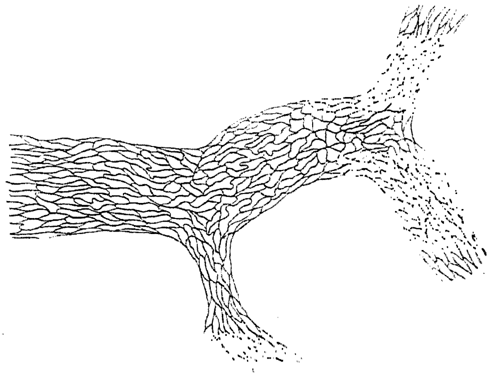
Thrombosis of the mesenteric veins produces very acute symptoms, similar to those of embolism of the mesenteric arteries (p. 673).

Infective emboli lodging in the portal venules give rise to a condition known as *septic or suppurative pylephlebitis* or, more shortly, *portal pyæmia*. They occur most often in one of the ileocolic radicles, and are due to appendicitis, but the infection may arise from anywhere in the portal system (e.g. the superior hæmorrhoidal radicles). Fragments of the infected clot break off from the original thrombus and lodge in the smaller veins of the liver, causing the development of multiple abscesses in its substance, and a rapidly fatal result. A similar path of infection is taken by the *entamœba histolytica* of dysentery, when it passes into the liver and produces *tropical abscess*.

THE LYMPHATIC SYSTEM

The lymphatic system includes the lymphatic vessels and lymph-glands. The lymphatic vessels form a closed system of vessels and contain a transparent fluid called *lymph* (p. 29). The lymphatic vessels of the small intestine receive the special designation of *lacteals* or *chyliferous vessels*; they differ in no respect from the lymphatic vessels generally, excepting that during the process of absorption of a fatty meal they contain a milk-white fluid, the *chyle*. In most of the tissues of the body there are minute spaces which contain a fluid resembling lymph, and formed by transudation from the blood-capillaries, but these spaces in the tissues are not continuous with the lymphatic vessels. "The lymphatics are concerned with the absorption of solids, and of material insoluble in water; the blood capillaries, on the other hand, are mainly associated with the absorption of material which is soluble in water." *

FIG. 749.—A small lymphatic vessel, from the diaphragm of a rabbit. Silvered. × 65.



The **lymphatic vessels** are exceedingly delicate, and their coats so transparent that the fluid they contain is readily seen through them. They are constricted at intervals and so present a knotted or beaded appearance; these constrictions correspond to the attachments of valves in the interior of the vessels. The lymphatic vessels unite with one another, and ultimately form two main channels, the *thoracic duct* and the *right lymphatic duct* which open into veins at the root of the neck. Lymphatic vessels have been found in nearly every texture and organ of the body which contains blood-vessels; they are absent from the central nervous system, and from non-vascular structures such as cartilage, nails, cuticle, and hair. "In an organ like the liver they are confined to the connective tissue of the capsule and of the portal spaces."

The **structure of the lymphatic vessels.**—The larger lymphatic vessels are each composed of three coats. The *internal* coat is thin, transparent, slightly elastic, and consists of a layer of elongated endothelial cells supported on an elastic membrane; the cells have wavy margins by which the contiguous cells are dovetailed into one another. The *middle* coat is composed of smooth muscular, and fine elastic fibres, disposed in a transverse direction. The *external* coat consists of connective tissue, intermixed with smooth muscular fibres longitudinally or obliquely disposed; it forms a protective covering to the other coats, and serves to connect the vessel with the neighbouring structures. In the smaller vessels there are no muscular or elastic fibres, and the wall consists only of a connective tissue coat lined by endothelium (fig. 749). The thoracic duct has a more complex structure than the other lymphatic vessels; it presents a distinct subendothelial layer, similar to that found in the arteries; in the middle coat there is, in addition to the muscular and elastic fibres, a layer of connective tissue with its fibres arranged longitudinally. The

* P. T. Herring and F. G. Macnaughton, *The Lancet*, June 3rd, 1922.

larger lymphatic vessels are supplied by nutrient vessels, which are distributed to their outer and middle coats; and here also have been traced many non-medullated nerves in the form of fine plexuses.

In the lymphatic vessels the valves are placed at much shorter intervals than in the veins. They are most numerous near the lymph-glands, and are found more frequently in the lymphatic vessels of the neck and upper extremity than in those of the lower extremity; they are wanting in the vessels composing the plexiform network in which the lymphatic vessels usually originate on the surface of the body. The valves are formed of thin layers of fibrous tissue covered on both surfaces by endothelium which presents the same arrangement as on the valves of veins (p. 573). They are semilunar in form, and are attached by their convex edges to the wall of the vessel, the concave edges being free and directed along the course of the lymph-current. Usually two valves, of equal size, are found opposite one another; but occasionally exceptions occur, especially at or near the anastomoses of lymphatic vessels; thus, one valve may be of small size and the other increased in proportion. The wall of a lymphatic vessel immediately above the attachment of each segment of a valve is expanded into a pouch or sinus which gives the vessel, when distended, the knotted or beaded appearance already referred to.

FIG. 750.—A section through a lymph-gland of a cat. Stained with hæmatoxylin and eosin. × 15.

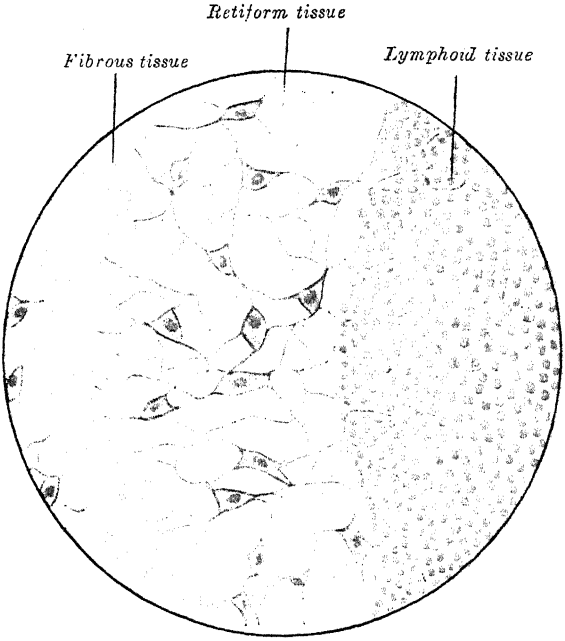
The **lymph-glands** are small oval or bean-shaped bodies, situated in the course of lymphatic and lacteal vessels so that the lymph and chyle pass through them on their way to the blood. Each generally presents on one side a slight depression, the *hilum*, through which the blood-vessels enter and leave the gland. The efferent lymphatic vessel also emerges from the gland at this spot, while the afferent vessels enter it at different parts of the periphery. On section (fig. 750), a lymph-gland displays two different structures: an external, of lighter colour—the *cortical*; and an internal, darker—the *medullary*. The cortical structure does not form a complete investment, but is deficient at the hilum, where the medullary portion reaches the surface of the gland; so that the efferent lymphatic vessel is derived directly from the medullary structure, while the afferent vessels empty themselves into the cortical substance.

The **structure of the lymph-glands** (figs. 750, 751). A lymph-gland consists of (1) a fibrous envelope, or *capsule*, from which a framework of processes (*trabeculæ*) proceeds inwards, imperfectly dividing the gland into open spaces freely communicating with each other; (2) a quantity of lymphoid tissue occupying these spaces without completely filling them; (3) a free supply of blood-vessels, which are supported in the trabeculæ; and (4) the *afferent* and *efferent lymphatic vessels* communicating through the lymph-paths in the substance of the gland. The nerves passing into the hilum are few in number and are chiefly distributed to the blood-vessels supplying the gland.

In man the *capsule* and *trabeculæ* are composed of connective tissue with some plain muscular fibres, but in many of the lower animals they consist almost entirely of the latter. The trabeculæ pass inwards towards the centre of the

gland for about one-third or one-fourth of the distance between the circumference and the centre of the gland. In some animals they are sufficiently well marked to divide the peripheral or cortical portion of the gland into a number of compartments, but in man this arrangement is not obvious. The larger trabeculæ springing from the capsule break up into finer bands, and these interlace to form a meshwork in the central or medullary portion of the gland. The gland-pulp or lymphoid tissue is arranged in masses in the cortex of the gland, but in the medulla these masses divide into cords which alternate with bands derived from the trabeculæ. The capsule and the trabeculæ are everywhere separated from the lymphoid tissue by a *lymph-path* or *lymph-sinus* which is bridged by a network of retiform tissue (fig. 751) and is continuous throughout the gland.

FIG. 751.—Retiform and adenoid tissue, from a lymph-gland. × 255.



The gland-pulp consists of ordinary lymphoid tissue (fig. 751), being made up of a delicate network of retiform tissue packed with lymphocytes. The network of the gland-pulp is continuous with that in the lymph-paths, but marked off from it by a closer reticulation; moreover, the fibres of the retiform tissue of the lymph-paths are continuous with those of the trabeculæ. The gland-pulp is traversed by a dense plexus of capillary blood-vessels. The nodules or follicles in the cortical portion of the gland frequently show areas where karyokinetic figures indicate a division of the lymph-corpuscles. These areas are termed *germ-centres*. The actively dividing cells have more abundant protoplasm than those which are not undergoing division, and consequently in stained sections the germ-centres appear clearer than the surrounding gland-pulp.

The *afferent vessels*, as stated above, enter at different parts of the periphery of the gland, and after branching and forming a dense plexus in the substance of the capsule, open into the lymph-sinuses of the cortical part. In doing this they lose all their coats except their endothelial lining, which is continuous with a layer of similar cells lining the lymph-paths. The *efferent vessel* commences from the lymph-sinuses of the medullary portion. The stream of lymph carried to the gland by the afferent vessels thus passes through the plexus in the capsule to the lymph-paths of the cortical portion, where it is exposed to the action of the gland-pulp; flowing through these it enters the paths or sinuses of the medullary portion, and finally emerges from the hilum by means of the efferent vessel. The stream of lymph in its passage through the lymph-sinuses is much retarded by the presence

of the reticulum, hence morphological elements, either normal or morbid, are easily arrested and deposited in the sinuses. Many lymph-corpuscles pass with the efferent lymph-stream to join the general blood-stream. The arteries of the gland enter at the hilum, and go to the gland-pulp, to break up into a capillary plexus, either directly or after running in the trabeculæ for a certain distance. The veins emerge from the gland at the hilum.

The lymphatic vessels are arranged into a superficial and a deep set. On the surface of the body the *superficial* lymphatic vessels are placed immediately beneath the skin and accompany the superficial veins; they join the deep lymphatic vessels in certain situations. In the interior of the body they lie in the submucous areolar tissue throughout the whole length of the digestive, respiratory and genito-urinary tracts; and in the subserous tissue of the thoracic and abdominal walls. Networks of minute lymphatic vessels are found interspersed among the elements and blood-vessels of the several tissues; the vessels composing the network as well as the meshes between them, are much larger than those of the capillary plexus. From these networks small vessels emerge, which pass, either to a neighbouring gland, or to join some larger lymphatic trunk. The *deep* lymphatic vessels, fewer in number but larger than the superficial, accompany the deep blood-vessels. Their mode of origin is probably similar to that of the superficial vessels.

The lymphatic vessels of any part or organ exceed the veins in number, but in size they are much smaller. Their anastomoses also, especially those of the large trunks, are more frequent, and are effected by vessels equal in diameter to those which they connect.

Applied Anatomy.—The lymphatic vessels and lymph-glands draining any infected area of the body are very liable to become inflamed, resulting in acute or chronic lymphangitis and lymphadenitis. In acute cases the paths of the superficial lymphatic vessels are often marked out on the skin by painful, red lines leading to tender, swollen lymph-glands, which may suppurate. Chronic lymphangitis, together with the blocking of numerous lymphatic vessels by the escaped ova of the minute parasitic worm *Microfilaria nocturna*, is the cause of elephantiasis, a condition common in the tropics and subtropics, and characterised by enormous enlargement and thickening of the skin of some part of the body, most frequently of the leg and scrotum. Tuberculous, syphilitic and cancerous enlargements of the lymphatic vessels and lymph-glands are very commonly met with. Primary tumours of the lymphatic vessels are lymphangioma and endothelioma; the so-called 'congenital cystic hygroma' of the neck, arm, trunk, or thigh, is a cystic lymphangioma.

The present view is that cancer spreads by permeating the lymphatic vessels as a solid cell-growth, rather than by minute emboli. Operations for the removal of cancer are therefore planned to take away in one mass the cancer, the intervening lymphatic vessels, and the lymph-glands.

The appearance of secondary malignant deposits or of secondary infection in parts of the body that seem not to be directly associated by any lymphatic connexion with the seat of the primary growth or infection has often been observed, and explained as due to 'retrograde transport' of cancer-cells or bacteria by a reversed flow of lymph. Weleminsky,* however, believes that the explanation is to be found in the fact that when the infected lymph-glands have grown to a certain size they no longer permit the normal flow of lymph through them, and that under these circumstances very delicate lymphatic connexions, whose existence normally remains unsuspected, develop to a surprising extent between groups of lymph-glands that at first sight appear to be unconnected with one another.

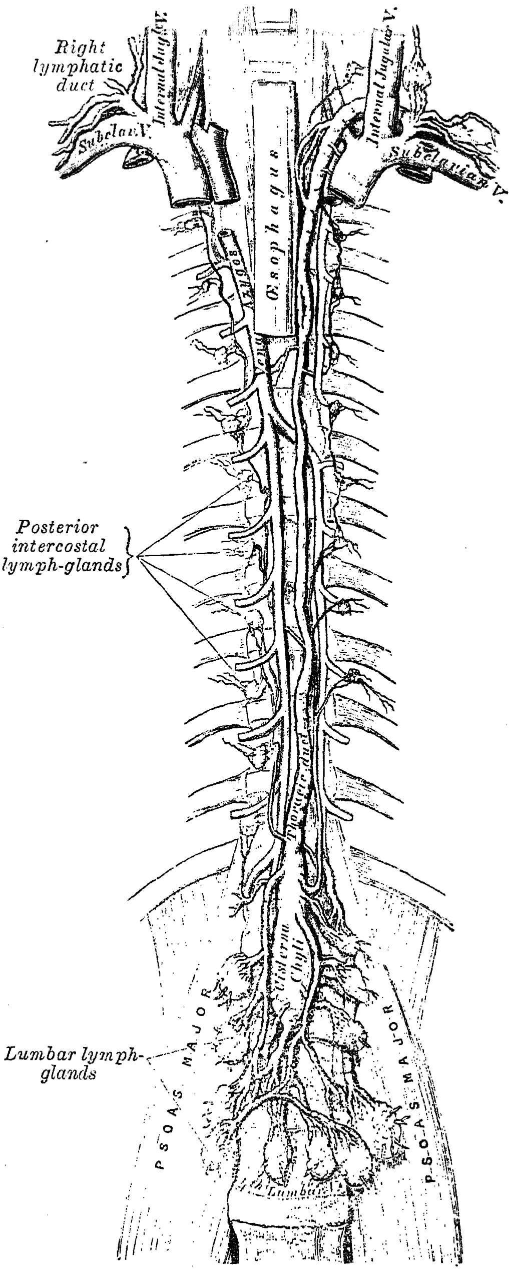
The Thoracic Duct

The **thoracic duct** (fig. 752) conveys the chyle and the greater part of the lymph into the blood. It is the common trunk of all the lymphatic vessels of the body, excepting those of the right side of the head, neck, and thoracic wall, the right upper extremity, right lung, right side of the heart, and part of the convex surface of the liver. In the adult it varies in length from 38 cm. to 45 cm. and extends from the second lumbar vertebra to the root of the neck. It begins in a dilatation, the *cisterna chyli*, which is from 5 cm. to 7 cm. long, and is situated on the front of the bodies of the first and second lumbar vertebræ, to the right side of and behind the aorta, by the side of the right crus of the Diaphragm. It enters the thorax through the aortic

* *Berliner klin. Woch.*, 1905, No. 24, p. 743.

hiatus of the Diaphragm, and ascends through the posterior mediastinal cavity with the aorta on its left and the azygos vein on its right side. Behind it in this region are the vertebral column and anterior longitudinal ligament, the right intercostal arteries, and the terminal parts of the hemiazygos and accessory hemiazygos veins. In front of it are the Diaphragm, œsophagus, and pericardium, the last being separated from it by a recess of the right pleural cavity. Opposite the fifth thoracic vertebra, it inclines towards the left side, enters the superior mediastinal cavity, and ascends on the right side of the aortic arch and behind the thoracic part of the left subclavian artery and between the left side of the œsophagus and the left pleura, to the upper orifice of the thorax. Passing into the neck it forms an arch which rises about 3 cm. or 4 cm. above the clavicle and turns forwards anterior to the first part of the subclavian artery, the vertebral artery and vein, and the thyreocervical trunk or its branches. It also passes in front of the phrenic nerve and the medial border of the Scalenus anterior, but is separated from these two structures by the prevertebral fascia. In front of it are the left common carotid artery, vagus nerve, and internal jugular vein. It ends by opening into the angle of junction of the left subclavian vein with the left internal jugular vein. The thoracic duct, at its commencement, is about equal in diameter to a goose-quill, but it diminishes considerably in calibre in the middle of the thorax, and is again slightly dilated just before its termination. It is generally flexuous, and constricted at intervals so as to present a varicose appearance. Not infrequently it divides in the middle of its course into two vessels of unequal size which soon reunite, or into several branches which form a plexiform interlacement. It occasionally divides at its upper part into two branches, right and left; the left ending in the usual manner, while the right opens into the right subclavian vein, in connexion with the right lymphatic duct. The thoracic duct has several valves; at its termination it is provided with a pair, the free borders of which are turned towards the vein, so as to prevent the passage of venous blood into the duct.

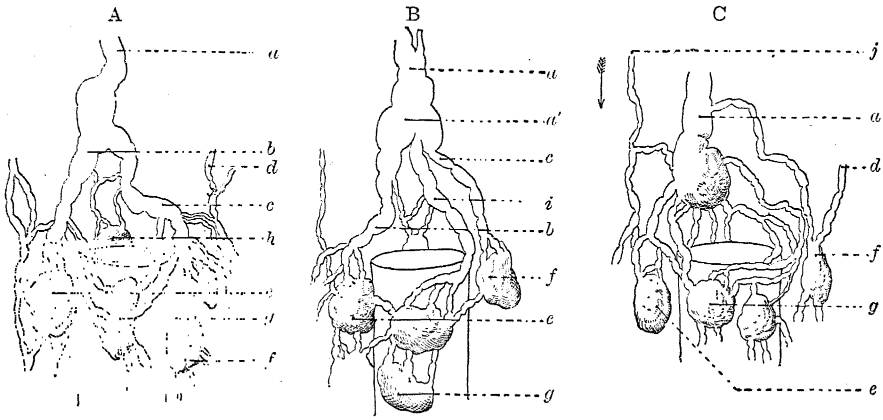
FIG. 752.—The thoracic and right lymphatic ducts.



The **cisterna chyli** (figs. 752, 753) receives the two lumbar lymphatic trunks, right and left, and the intestinal lymphatic trunk. The *lumbar trunks* are formed by the union of the efferent vessels from the lateral aortic lymph-glands; they receive the lymph from the lower limbs, from the walls and viscera of the pelvis, from the kidneys and suprarenal glands, and the deep lymphatics of the greater part of the abdominal wall. The *intestinal trunk* receives the lymph from the stomach, intestine, pancreas and spleen, and from the lower and front part of the liver.

Tributaries.—Opening into the commencement of the thoracic duct, on either side, is a descending trunk from the posterior intercostal lymph-glands of the lower six or seven intercostal spaces. In the thorax the duct is joined on either side by a trunk which drains the upper lumbar lymph-glands and pierces the crus of the Diaphragm. It also receives the efferents from the posterior mediastinal lymph-glands and from the posterior intercostal lymph-glands of the upper six left spaces. In the neck it is joined by the *left jugular trunk* from the left side of the head and neck, and *left subclavian trunk* from

FIG. 753.—Modes of origin of the thoracic duct. (Poirier and Charpy.)



a. Thoracic duct. *a'*. Cisterna chyli. *b*, *c*. Efferent trunks from lateral aortic lymph-glands. *d*. An efferent vessel which pierces the left crus of the Diaphragm. *e*, *f*. Lateral aortic lymph-glands. *g*. Pre-aortic lymph-glands. *h*. Retro-aortic lymph-glands. *i*. Intestinal trunk. *j*. Descending branch from intercostal lymphatics.

the left superior extremity; sometimes it is joined by the *left bronchomediastinal trunk*, but this trunk usually opens independently into the junction of the left subclavian and internal jugular veins.

The **right lymphatic duct** (fig. 752), about 1 cm. in length, courses along the medial border of the Scalenus anterior at the root of the neck, and ends by opening into the angle of junction of the right subclavian and right internal jugular veins. Its orifice is guarded by two semilunar valves which prevent the passage of venous blood into the duct.

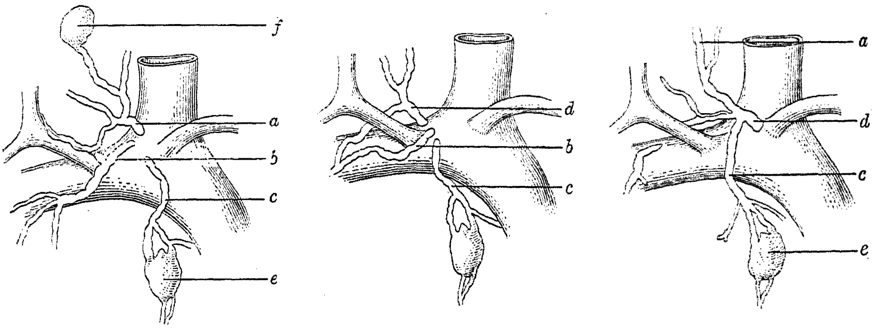
Tributaries.—The right lymphatic duct receives the lymph from the right side of the head and neck through the *right jugular trunk*; from the right upper extremity through the *right subclavian trunk*; from the right side of the thorax, right lung, right side of the heart, and part of the convex surface of the liver, through the *right bronchomediastinal trunk*. These three trunks frequently open separately in the angle of union of the two veins (fig. 754).

Applied Anatomy.—Blockage of the thoracic duct by mature specimens of the minute parasitic worm *Microfilaria nocturna* gives rise to stasis of the chyle, and to its passage in various abnormal directions on its course past the obstruction. The neighbouring abdominal, renal, and pelvic lymphatics become enlarged, varicose, and tortuous, and chyle may make its way into the urine (chyluria), the tunica vaginalis (chylocele), the abdominal cavity (chylous ascites) or the pleural cavity (chylous pleural effusion), in consequence of rupture of some of these distended lymphatic vessels.

Gunshot wounds of the chest involving laceration of the thoracic duct and the escape of chyle into the pleural cavity have been described. It appears that if left alone, such lacerations tend to heal and close up spontaneously.

The thoracic duct may be secondarily infected in intestinal or pulmonary tuberculosis, and may contain either miliary tubercles, caseating tuberculous masses, or even tuberculous ulcers. It is often the seat of secondary carcinomatous deposits in cases of cancer of some abdominal viscus, becoming infiltrated throughout until it becomes a stiff moniliform rod as thick as a pencil, with multiple stenoses and dilatations of its lumen; in such cases the left supraclavicular lymph-glands are often infected and enlarged, while the lungs remain free from secondary growths.

Fig. 754.—The terminal lymphatic trunks of the right side. (Poirier and Charpy.)



a. Jugular trunk. *b.* Subclavian trunk. *c.* Bronchomediastinal trunk. *d.* Right lymphatic trunk. *e.* Lymph-gland of internal mammary chain. *f.* Lymph-gland of deep cervical chain.

The thoracic duct has been wounded in removing tuberculous glands from the neck. When this happens the duct should be ligatured in the same way as a vein. The chyle then appears to find its way into the veins by anastomosing channels.

THE LYMPH-GLANDS OF THE HEAD AND NECK

1. The **lymph-glands of the head** (fig. 755) consist of the following groups:

Occipital.	Parotid.	Deep facial.
Posterior auricular.	Facial.	Lingual.
Anterior auricular.		

The **occipital lymph-glands**, one to three in number, are placed on the back of the head on the upper part of the Trapezius, or, if there be a gap here between the Trapezius and the Sternocleidomastoideus, on the insertion of the Semispinalis capitis. Their afferent vessels drain the lymph from the occipital region of the scalp; their efferents convey it to the superior deep cervical lymph-glands.

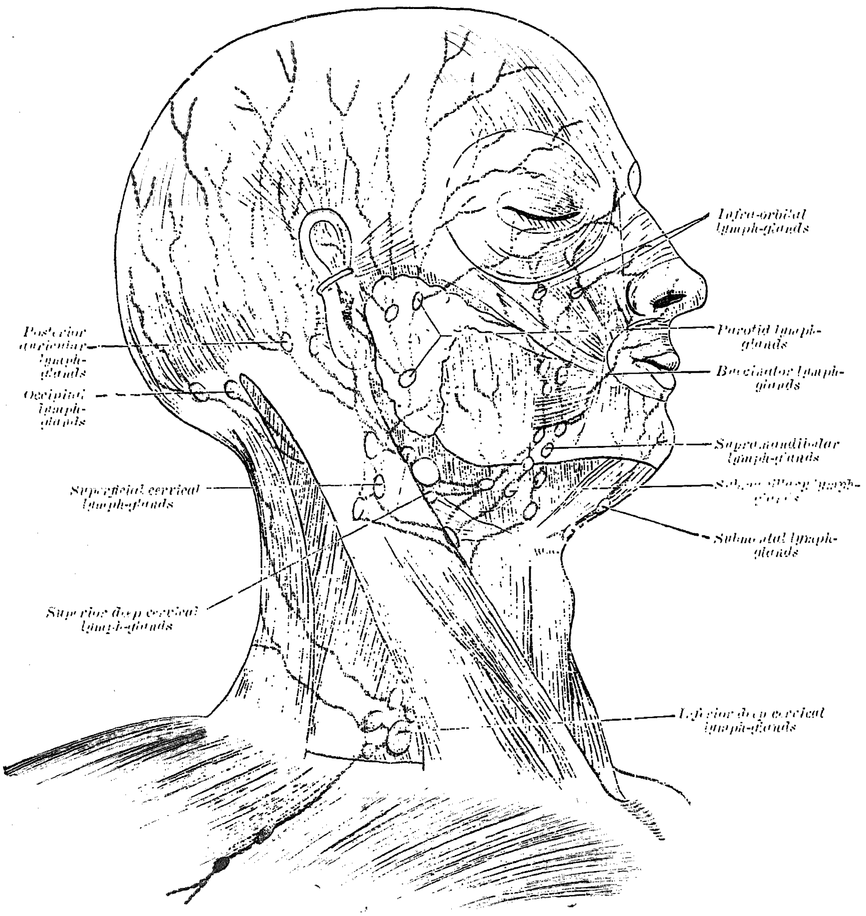
The **posterior auricular lymph-glands**, usually two in number, are situated on the mastoid insertion of the Sternocleidomastoideus, beneath the Auricularis posterior. Their afferent vessels drain the posterior part of the temporoparietal region, the upper part of the cranial surface of the auricula or pinna, and the back of the external acoustic meatus; their efferents pass to the superior deep cervical lymph-glands.

The **anterior auricular lymph-glands**, from one to three in number, lie immediately in front of the tragus. Their afferents drain the lateral surface of the auricula and the skin of the adjacent part of the temporal region; their efferents pass to the superior deep cervical lymph-glands.

The **parotid lymph-glands** form two groups, one imbedded in the substance of the parotid salivary gland, and the other, or subparotid group, placed on the lateral wall of the pharynx. Occasionally small lymph-glands are found in the subcutaneous tissue over the parotid salivary gland. The afferents of the subparotid lymph-glands drain the nasal part of the pharynx and the posterior parts of the nasal cavities; their efferents pass to the superior deep cervical lymph-glands. The afferents of the remaining parotid lymph-glands drain the root of the nose, the eyelids, the frontotemporal region, the external acoustic meatus and the tympanic cavity, possibly also the posterior parts of the palate and of the floor of the nasal cavity. Their efferents pass to the superior deep cervical lymph-glands.

The **facial lymph-glands** (figs. 755, 756) comprise three groups: (*a*) *infra-orbital*, scattered over the infra-orbital region from the groove between the nose and cheek to the zygomatic arch; (*b*) *buccinator*, one or more on the Buccinator opposite the angle of the mouth; (*c*) *supramandibular*, on the outer surface of the mandible in front of the Masseter and in contact with the external maxillary artery and anterior facial vein. Their afferents drain the eyelids, the conjunctiva, and the skin and mucous membrane of the nose and cheek; their efferents pass to the anterior auricular and submaxillary lymph-glands.

Fig. 755.—The superficial lymph-glands and lymphatic vessels of the head and neck.



The **deep facial lymph-glands** are placed beneath the ramus of the mandible, on the outer surface of the Pterygoideus externus, in relation to the internal maxillary artery. Their afferents drain the temporal and infra-temporal fossæ, the palate and the nasal part of the pharynx; their efferents pass to the superior deep cervical lymph-glands.

The **lingual lymph-glands** are two or three small inconstant nodules lying on the Hyoglossus and between the Genioglossi. They are merely glandular nodules in the course of the lymphatic vessels of the tongue.

2. The **lymph-glands of the neck** include the following groups:

Retropharyngeal.	Anterior cervical.
Submaxillary.	Superficial cervical.
Submental.	Deep cervical.

The **retropharyngeal lymph-glands** (fig. 757), from one to three in number, lie in the buccopharyngeal fascia, behind the upper part of the pharynx

and in front of the arch of the atlas, being separated, however, from the latter by the Longus capitis. Their afferents drain the posterior parts of the nasal cavities, the nasal part of the pharnyx, and the auditory tubes; their efferents pass to the superior deep cervical lymph-glands.

The **submaxillary lymph-glands** (figs. 755, 756), usually three in number, are placed between the lower border of the mandible and the submaxillary salivary gland. One lies at the anterior end of the salivary gland, one in front of, and another behind the external maxillary artery as it reaches the mandible. The middle gland is the most constant (Stahr). Small lymph-glands are sometimes found imbedded in the submaxillary salivary gland or lying on its deep surface. The afferents of the submaxillary lymph-glands drain the medial palpebral commissure, the cheek, the side of the nose, the upper lip, the lateral

Fig. 756.—The lymphatics of the face. (After Küttner.)

part of the lower lip, the gums, and the margin of the tongue; efferent vessels from the facial and submental lymph-glands also enter the submaxillary lymph-glands. Their efferent vessels pass to the superior deep cervical lymph-glands.

The **submental or suprahyoid lymph-glands,** three or four in number, are placed between the anterior bellies of the two Digastric muscles. Their afferents drain the central portions of the lower lip and floor of the mouth, and the apex of the tongue; their efferents pass to the submaxillary and jugulo-omohyoid lymph-glands.

The **anterior cervical lymph-glands** are placed in front of the larynx and trachea, and consist of a *superficial* and a *deep* set. Those of the superficial set lie alongside the anterior jugular vein, but are inconstant in number and size. Those of the deep set comprise: (*a*) the *infrahyoid lymph-glands* which lie in front of the hyothyreoid membrane, and receive their afferents from the neighbourhood of the epiglottis; (*b*) the *prelaryngeal lymph-glands*, which lie on the middle cricothyreoid ligament; and (*c*) the *pretracheal lymph-glands* which are placed in front of the trachea, alongside the inferior thyreoid veins. The prelaryngeal and pretracheal groups receive their afferents from the larynx, the thyreoid gland, and the cervical part of the trachea; their efferents pass to the deep cervical lymph-glands.

The **superficial cervical lymph-glands** (fig. 755) lie in close relationship with the external jugular vein as it emerges from the parotid gland, and are superficial to the Sternocleidomastoideus. Their afferents drain the parotid region and the lower part of the auricula, while their efferents pass round the

anterior margin of the Sternocleidomastoideus to join the superior deep cervical lymph-glands.

The **deep cervical lymph-glands** (figs. 757, 758) are numerous and of large size; they form a chain along the carotid sheath, lying by the side of the pharynx, œsophagus, and trachea, and extending from the base of the skull to the root of the neck. They are usually described in two groups, superior and inferior. The *superior deep cervical lymph-glands* lie under the Sternocleidomastoideus in close relation with the accessory and hypoglossal nerves and the internal jugular vein, some of the glands lying in front of and others behind the vein. One cluster of this group is closely associated with the lymphatic vessels of the tongue. It is placed in the triangle formed by the posterior belly of the Digastricus, the common facial vein, and the internal jugular vein, and consists of one large and several small glands which from their situation may be named the *jugulo-digastric* lymph-glands. The *inferior deep cervical lymph-glands* are situated in the supraclavicular triangle, and under cover of the lower part of the Sternocleidomastoideus, where they are closely related to the brachial plexus and the subclavian vessels. One gland of this group is closely related to the lymphatic vessels of the tongue. It lies beneath the anterior part of the Sternocleidomastoideus on or just above the central tendon of the Omohyoideus, and may therefore be named the *jugulo-omohyoid* lymph-gland (Jamieson and Dobson).* A few *paratracheal lymph-glands* are situated alongside the recurrent nerves on the lateral aspects of the trachea and œsophagus. The superior deep cervical lymph-glands drain the occipital portion of the scalp, the upper part of the auricula, the back of the neck, a considerable part of the tongue, the larynx, thyreoid gland, trachea, nasal part of the pharynx, nasal cavities, tonsils, palate, and œsophagus. They receive also the efferent vessels from all the other lymph-glands of the head and neck, except those from the inferior deep cervical lymph-glands. The inferior deep cervical lymph-glands drain the back of the scalp and neck, the superficial pectoral region, and the lateral part of the arm and forearm (p. 760). In addition, they receive vessels from the superior deep cervical lymph-glands. The efferents of the superior deep cervical lymph-glands pass partly to the inferior deep cervical lymph-glands and partly to a trunk which unites with the efferent vessel of the inferior deep cervical lymph-glands and forms the *jugular trunk*. On the right side, this trunk ends in the junction of the internal jugular and subclavian veins; on the left side it joins the thoracic duct.

THE LYMPHATIC VESSELS OF THE HEAD AND NECK

The *lymphatic vessels of the scalp* are divisible into (*a*) those of the frontal region, which drain into the anterior auricular and parotid lymph-glands; (*b*) those of the temporoparietal region, which end in the parotid and posterior auricular lymph-gands; and (*c*) those of the occipital region, which terminate partly in the occipital lymph-glands and partly in a trunk which runs down along the posterior border of the Sternocleidomastoideus to end in the inferior deep cervical lymph-glands.

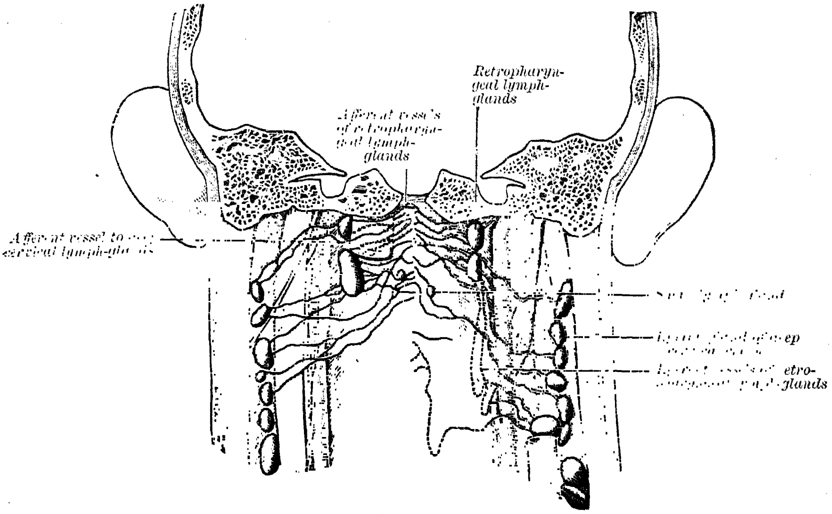
The *lymphatic vessels of the auricula and external acoustic meatus* are also divisible into three groups: (*a*) an anterior, from the lateral surface of the auricula and anterior wall of the meatus to the anterior auricular lymph-glands; (*b*) a posterior, from the margin of the auricula, the upper part of its cranial surface, the internal surface and posterior wall of the meatus to the posterior auricular and superior deep cervical lymph-glands; (*c*) an inferior, from the floor of the meatus and from the lobule of the auricula to the superficial and superior deep cervical lymph-glands.

The *lymphatic vessels of the face* (figs. 755, 756) are more numerous than those of the scalp. Those from the eyelids and conjunctiva consist of a superficial plexus in the subcutaneous tissue, and a deep plexus in front of and behind the tarsi; these plexuses anastomose with one another, and open into medial and lateral groups of lymphatic vessels. The vessels of the medial

* Consult an article by J. K. Jamieson and J. F. Dobson on 'The lymphatics of the tongue,' *British Journal of Surgery*, vol. viii. No. 29, 1920.

group drain the caruncula lacrimalis, the skin of the medial commissure and of the adjoining part of the upper eyelid, and the skin and conjunctiva of approximately the medial one-half of the lower eyelid; they accompany the anterior facial vein, and open into the submaxillary lymph-glands. The vessels of the lateral group drain the skin of the greater part, and the conjunctiva of the whole, of the upper eyelid, and the skin and conjunctiva of the lateral part of the lower eyelid; they open into the parotid lymph-glands. The lymphatic vessels from the posterior part of the cheek pass to the parotid lymph-glands; those from the anterior portion of the cheek, the side of the nose, the upper lip, and the lateral portions of the lower lip, end in the submaxillary lymph-glands. The deeper vessels from the temporal and infratemporal fossæ pass to the deep facial and superior deep cervical lymph-glands. The deeper vessels of the cheek and lips end, like the superficial, in the submaxillary lymph-glands. Both superficial and deep vessels of the central part of the lower lip run to the submental lymph-glands.

FIG. 757.—The lymphatics of the pharynx. (Poirier and Charpy.)



The *lymphatic vessels of the nasal cavities* can be injected from the subdural and subarachnoid cavities. Those from the anterior parts of the nasal cavities communicate with the lymphatic vessels of the skin of the nose, and end in the submaxillary lymph-glands; those from the posterior two-thirds of the nasal cavities and from the accessory air-sinuses of the nose pass partly to the retropharyngeal and partly to the superior deep cervical lymph-glands.

The *lymphatic vessels of the mouth.*—The vessels of the gums pass to the submaxillary lymph-glands; those of the hard palate are continuous in front with those of the upper gum, but run backwards to pierce the Constrictor pharyngis superior, and end in the superior deep cervical and subparotid lymph-glands; those of the soft palate pass backwards and lateralwards and end partly in the retropharyngeal and subparotid, and partly in the superior deep cervical, lymph-glands. The vessels of the anterior part of the floor of the mouth go either directly to the inferior lymph-glands of the superior deep cervical group, or indirectly through the submental lymph-glands; the vessels from the rest of the floor of the mouth pass to the submaxillary and superior deep cervical lymph-glands.

The *lymphatic vessels of the teeth.*—Lymphatic vessels were demonstrated in the pulps of the teeth by Schweitzer * in 1907, and his observations have been confirmed by Dewey and Noyes.† They pass to the submaxillary and deep cervical lymph-glands.

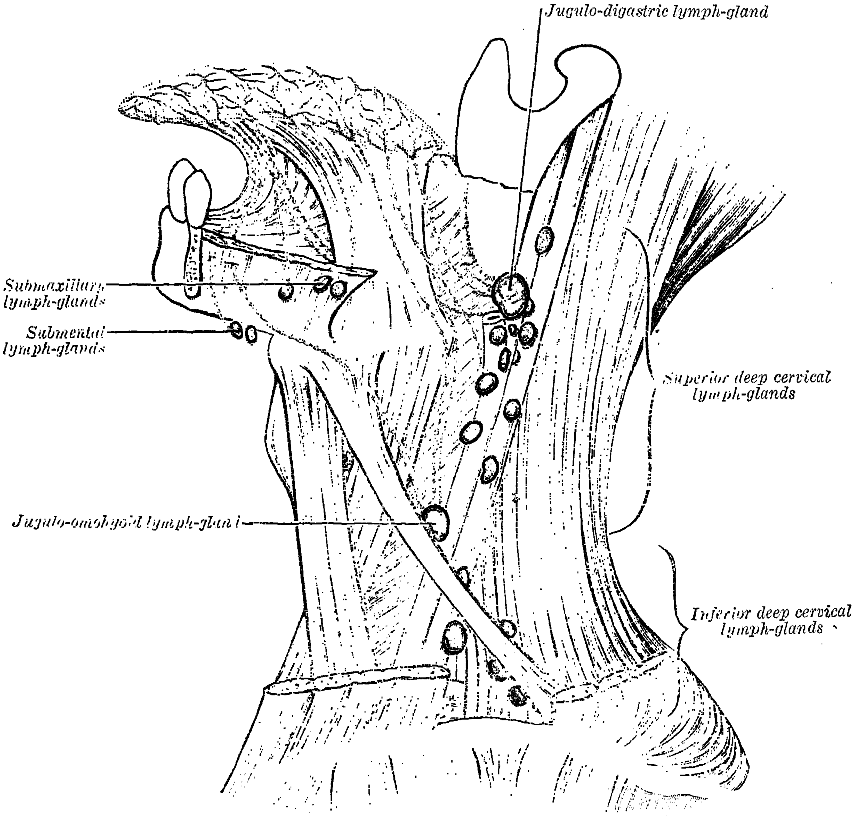
The *lymphatic vessels of the palatine tonsil*, usually three to five in number, pierce the buccopharyngeal fascia and Constrictor pharyngis superior and pass

* *Archiv. für Mikrosk. Anat. u. Entwickl.*, 1907 and 1909. † *Dental cosmos*, vol. lix. No. 4.

between the Stylohyoideus and the internal jugular vein to the superior deep cervical lymph-glands. Most of them end in a lymph-gland which lies at the side of the posterior belly of the Digastricus, on the internal jugular vein; occasionally one or two additional vessels run to small lymph-glands on the lateral side of the vein, under cover of the Sternocleidomastoideus.

The *lymphatic vessels of the tongue* (figs. 758, 759).*—The lymphatic plexus in the mucous membrane of the tongue is continuous with the intramuscular plexus. The part of the tongue in front of the papillæ vallatæ is drained into marginal and central lymphatic vessels.

FIG. 758.—The course of the lymphatic vessels from the tongue to the submental, submaxillary, and deep cervical lymph-glands. (Jamieson and Dobson.) *British Journal of Surgery*, vol. viii. 1920.



1. *Marginal vessels.*—The lymphatic vessels from the tip, and region of the frænum, of the tongue descend under the mucous membrane and end in widely distributed lymph-glands.

(*a*) Vessels pierce the origin of the Mylohyoideus in contact with the periosteum of the mandible; one or two of these vessels enter the submental lymph-glands, and one descends over the hyoid bone to the jugulo-omohyoid lymph-gland. (It should be noted (1) that vessels arising in the plexus on one side of the tongue may cross under the frænum and end in the lymph-glands of the opposite side, and (2) that the efferent vessels of the median-placed submental lymph-glands pass impartially to either side.)

(*b*) Some vessels pierce the origin of the Mylohyoideus, and enter the anterior or the middle submaxillary lymph-gland.

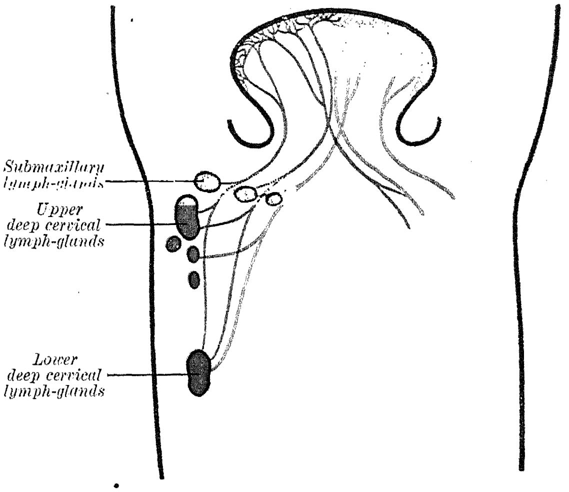
(*c*) Some vessels pass deeply under the sublingual salivary gland, and accompanying the ranine vein, end in the jugulo-digastric lymph-glands. One vessel

* This description of the lymphatic vessels of the tongue is based on the researches of Jamieson and Dobson (*loc. cit.* p. 754).

often descends over or beneath the central tendon of the Digastricus to reach the jugulo-omohyoid lymph-gland.

Some of the lymphatic vessels from the lateral margin of the tongue pass over the sublingual salivary gland, pierce the Mylohyoideus, and end in the submaxillary lymph-glands; others pass under the salivary gland and end in the jugulo-digastric glands.

Fig. 759.—A diagram to show the course of the central lymphatic vessels of the tongue to the lymph-glands on both sides of the neck. (Jamieson and Dobson.) *British Journal of Surgery*, vol. viii. 1920.



The vessels from the posterior part of the margin of the tongue make their way through the pharyngeal wall to the jugulo-digastric lymph-glands.

2. *Central vessels.*—There is no clear line of demarcation between areas on the surface of the tongue draining into the marginal or into the central vessels. The central lymphatic vessels descend in the middle line between the Genioglossi. Some turn lateralwards through the muscles, but the majority appear between their free borders and diverge to the right or left, i.e. the vessels from one side of the tongue may run to the lymph-glands of the opposite side. They follow the lingual blood-vessels, and end in the deep cervical lymph-glands, especially in the jugulo-digastric and jugulo-omohyoid glands. Some pierce the Mylohyoideus and enter the submaxillary lymph-glands.

3. *Dorsal vessels.*—The vessels draining the area of the papillæ vallatæ, and the part of the tongue behind these papillæ, run backwards—those near the middle line may divide and run to both sides. They turn lateralwards to join the marginal vessels, and all pierce the pharyngeal wall passing in front of or behind the external carotid artery, to reach the jugulo-digastric and jugulo-omohyoid lymph-glands, or the glands between them. One vessel may descend behind the hyoid bone, perforate the hyothyreoid membrane, and end in the jugulo-omohyoid lymph-gland.

The *lymphatic vessels of the skin and muscles of the neck* pass to the deep cervical lymph-glands. From the upper part of the *pharynx* the lymphatic vessels pass to the retropharyngeal lymph-glands; from the lower part to the deep cervical lymph-glands. From the *larnyx* two sets of vessels arise, an upper and a lower which do not communicate very freely, the two sets being separated by the vocal folds where there are very few lymphatic vessels. The vessels of the upper set pierce the hyothyreoid membrane, accompany the laryngeal branch of the superior thyreoid artery, and join the superior deep cervical lymph-glands. Of the lower set, some pierce the conus elasticus and join the pretracheal and prelaryngeal lymph-glands; others run between the cricoid cartilage and first tracheal ring and enter the inferior deep cervical lymph-glands. The lymphatic vessels of the *thyreoid gland* consist of an upper set, which accompanies the superior thyreoid artery and enters the superior deep cervical lymph-glands, and a lower, which runs partly to the pretracheal lymph-glands and partly to the small paratracheal lymph-glands which accompany the recurrent nerves. The paratracheal lymph-glands also receive lymphatic vessels from the cervical portion of the trachea.

Applied Anatomy.—The superficial and deep cervical lymph-glands often become infected from inflammatory conditions about the mouth, teeth, tonsil and pharynx. When suppuration occurs in the deep group it is apt to spread widely beneath the deep cervical fascia unless relieved by early incision.

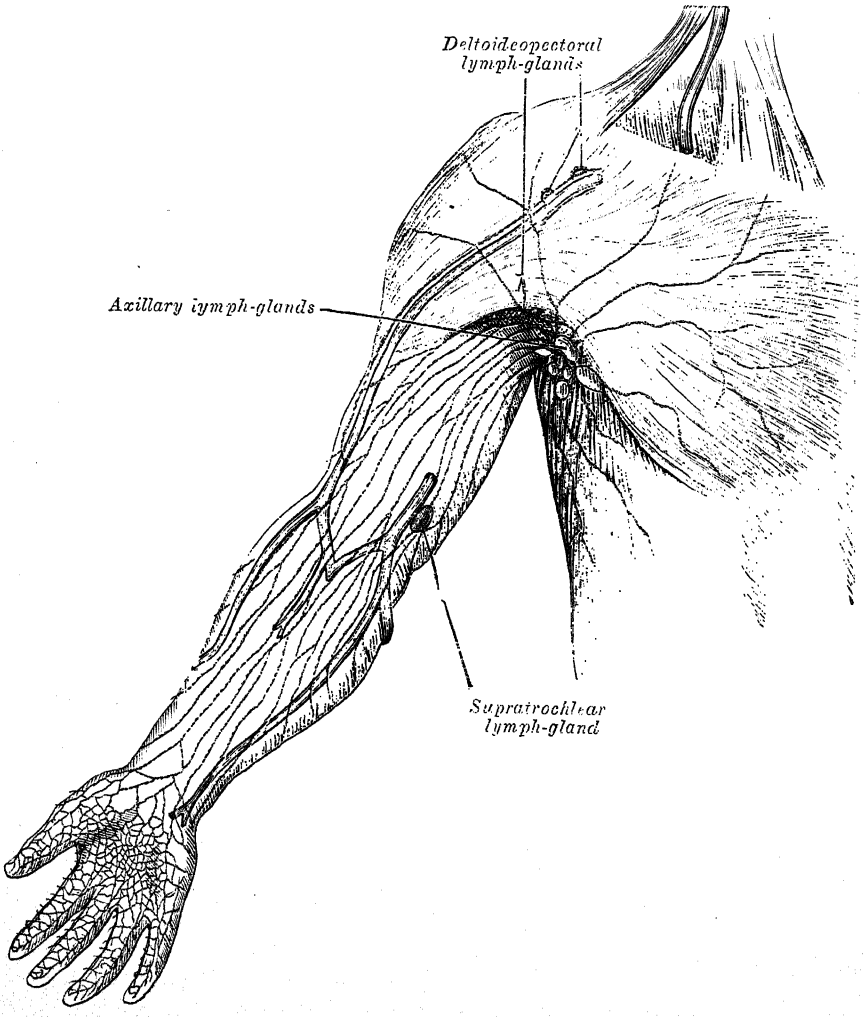
The cervical lymph-glands are very frequently the seat of tuberculous disease. This condition may be set up by some lesion in those parts from which they receive their lymph. It is very desirable for the surgeon, in dealing with these cases, to possess a knowledge of the relation of the groups of lymph-glands to important structures, as in order to eradicate them by operation a long and difficult dissection may be required. The same can be said of these lymph-glands when they become infiltrated with carcinomatous growth secondary to disease of the lip, tongue, palate, or pharynx. At times it will be found necessary to remove a portion of the internal jugular vein, previously ligatured, with the mass of glands.

When an acute abscess forms in the retropharyngeal glands, it is opened by an incision through the posterior pharyngeal wall, but a chronic abscess in these glands is opened by making an incision behind the Sternomastoideus and the carotid sheath, at the level of the second cervical vertebra.

THE LYMPH-GLANDS OF THE UPPER EXTREMITY

The **lymph-glands of the upper extremity** are divided into two sets, *superficial* and *deep*.

FIG. 760.—The superficial lymph-glands and lymphatic vessels of the upper extremity.

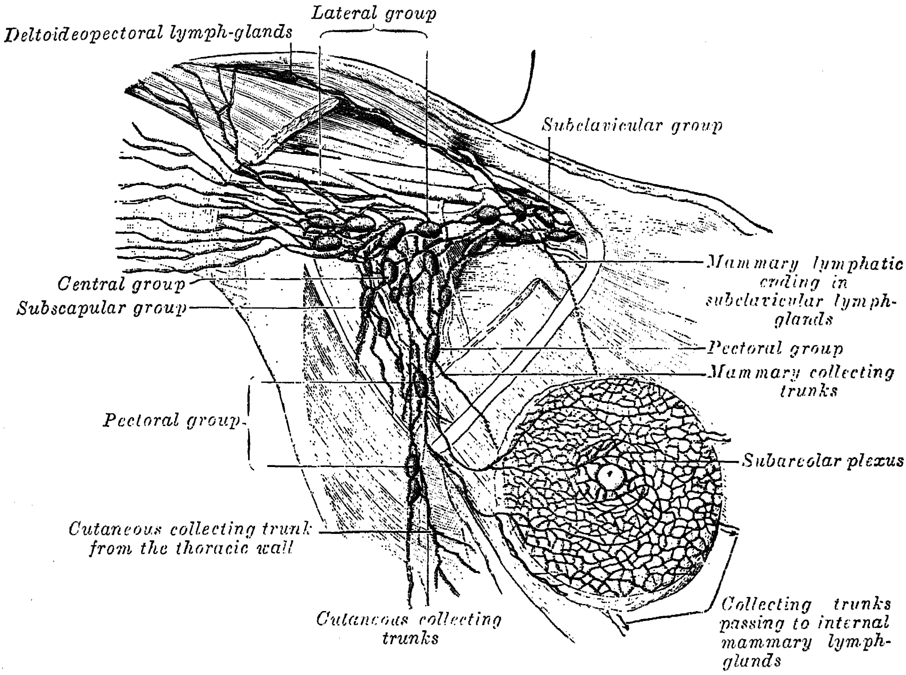


The **superficial lymph-glands** (fig. 760) are few and of small size. One or two *supratrochlear* lymph-glands are placed above the medial epicondyle

of the humerus, on the medial side of the basilic vein. Their afferents drain the middle, ring, and little fingers, the medial portion of the hand, and the superficial area over the ulnar side of the forearm ; these vessels are, however, in free communication with the other lymphatic vessels of the forearm. Their efferents accompany the basilic vein and join the deeper vessels. One or two *deltoideopectoral* lymph-glands are found beside the cephalic vein, between the Pectoralis major and Deltoideus, immediately below the clavicle. They are situated in the course of a collecting trunk which drains the lateral side of the arm and forearm.

The **deep lymph-glands** are chiefly grouped in the axilla, although a few may be found in the forearm, in the course of the radial, ulnar, and interosseous vessels, and in the arm along the medial side of the brachial artery.

Fig. 761.—The lymphatics of the mamma, and the axillary lymph-glands. Semi-diagrammatic. (Poirier and Charpy.)



The **axillary lymph-glands** (fig. 761) are of large size ; they vary from twenty to thirty in number, and may be divided into five groups :

1. A *lateral group* of from four to six lymph-glands lies in relation to the medial and posterior aspects of the axillary vein ; the afferents of this group drain the whole arm with the exception of that portion whose lymphatic vessels accompany the cephalic vein. The efferent vessels pass partly to the central and subclavicular groups of axillary lymph-glands, and partly to the inferior deep cervical lymph-glands.

2. An *anterior or pectoral group*, consisting of four or five lymph-glands, lies along the lower border of the Pectoralis minor, in relation with the lateral thoracic artery. Its afferents drain the skin and muscles of the anterior and lateral walls of the body, above the level of the umbilicus, and the central and lateral parts of the mamma (p. 777) ; its efferents pass partly to the central, and partly to the subclavicular groups of axillary lymph-glands.

3. A *posterior or subscapular group* of six or seven lymph-glands is placed along the lower margin of the posterior wall of the axilla in the course of the subscapular artery. The afferents of this group drain the skin and muscles of the lower part of the back of the neck and of the posterior thoracic wall ; their efferents pass to the central group of axillary lymph-glands.

4. A *central or intermediate group* of three or four large lymph-glands is imbedded in the adipose tissue near the base of the axilla. Its afferents are the efferent vessels of all the preceding groups of axillary lymph-glands: its efferents pass to the subclavicular group of lymph-glands.

5. A *medial or subclavicular group* of six to twelve lymph-glands is situated partly posterior to the upper portion of the Pectoralis minor and partly above the upper border of this muscle. The only direct territorial afferents of this group are those which accompany the cephalic vein and one which drains the upper peripheral part of the mamma, but it receives the efferents of all the other axillary lymph-glands. The efferent vessels of this group unite to form the *subclavian trunk*, which opens either directly into the junction of the internal jugular and subclavian veins or into the jugular lymphatic trunk: on the left side it may end in the thoracic duct. A few efferents from the subclavicular group usually pass to the inferior deep cervical lymph-glands.

Applied Anatomy.—Enlargement of the axillary lymph-glands is very often found in malignant disease and also in infective processes implicating the upper part of the back and shoulder, the front of the chest and mamma, the upper part of the front and side of the abdomen, or the hand, forearm, and arm.

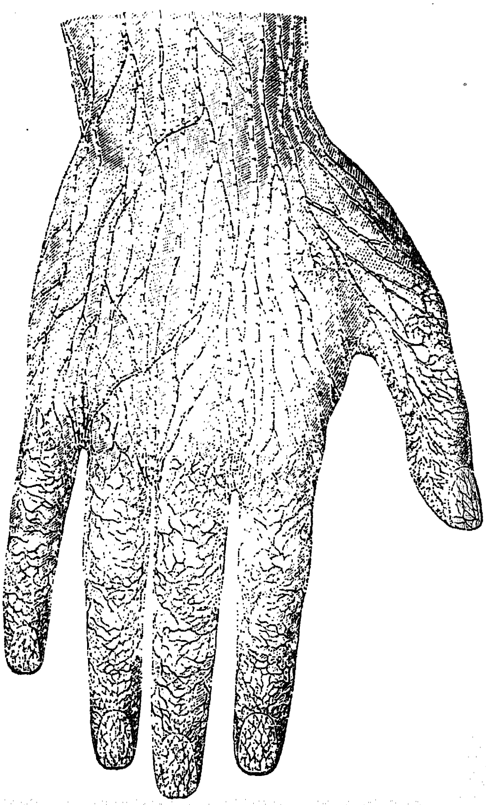
In the operation for the removal of a cancerous breast, all the axillary lymph-glands, the lymphatic vessels, and the Pectorales major et minor are removed in one mass.

THE LYMPHATIC VESSELS OF THE UPPER EXTREMITY

The *lymphatic vessels of the upper extremity* consist of two sets, superficial and deep.

The *superficial lymphatic vessels* (fig. 762) commence in the lymphatic plexus which everywhere pervades the skin; the meshes of the plexus are much finer in the palm and on the flexor aspects of the digits than elsewhere. The digital plexuses are drained by a pair of vessels which run on the sides of each digit, and incline backwards to reach the dorsum of the hand. From the dense plexus of the palm, vessels pass in different directions, viz. upwards towards the wrist, downwards to join the digital vessels, medialwards to join the vessels on the ulnar border of the hand, and lateralwards to those on the thumb. Several vessels from the central part of the plexus unite to form a trunk, which passes round the metacarpal bone of the index finger to join the vessels on the dorsum of that digit and on the dorsum of the thumb. As the lymphatic vessels ascend on the dorsal and palmar surfaces of the wrist, they are collected into groups, which accompany the cephalic, median antibrachial, and basilic veins in the forearm. A few of those on the medial side end in the supratrochlear lymph-glands, but the majority pass directly to the lateral group of axillary lymph-glands. Some of the vessels on the lateral side are collected into

Fig. 762.—The lymphatic vessels of the dorsal surface of the hand. (Sappey.)



a trunk which ascends with the cephalic vein to the deltoideo-pectoral lymph-glands; the efferents from this group enter either the subclavicular axillary lymph-glands or pass over the clavicle to the inferior deep cervical lymph-glands.

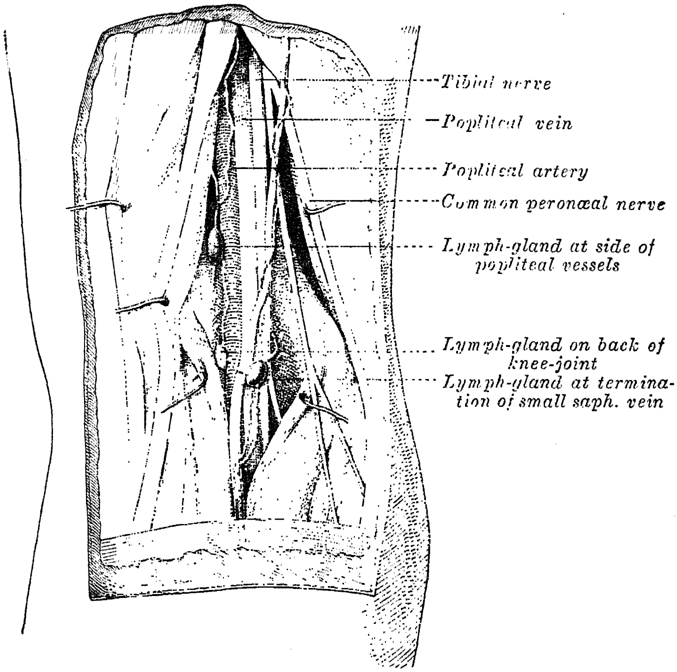
The *deep lymphatic vessels* accompany the deep blood-vessels. In the forearm, they consist of four sets, corresponding with the radial, ulnar, volar interosseous, and dorsal interosseous arteries; they communicate at intervals with the superficial lymphatic vessels, and some of them end in the lymph-glands which are occasionally found beside the arteries. A few end in the supratrochlear lymph-glands, but most of them pass to the lateral group of axillary lymph-glands.

THE LYMPH-GLANDS OF THE LOWER EXTREMITY

The **lymph-glands of the lower extremity** consist of three sets:—the anterior tibial, the popliteal and the inguinal.

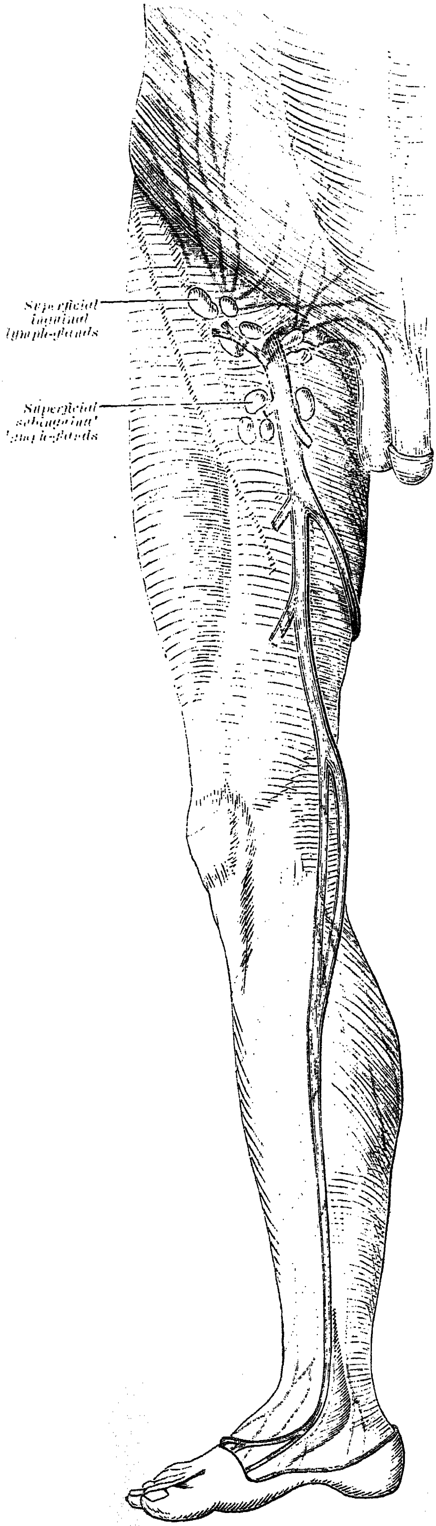
The **anterior tibial lymph-gland** is small and inconstant; it lies on the interosseous membrane in relation to the upper part of the anterior tibial vessels.

FIG. 763.—The lymph-glands of the popliteal fossa. (Poirier and Charpy.)



The **popliteal lymph-glands** (fig. 763), small in size and six or seven in number, are imbedded in the fat contained in the popliteal fossa. One lies near the termination of the small saphenous vein, and drains the region from which this vein derives its tributaries. Another is placed between the popliteal artery and the posterior surface of the knee-joint; it receives the lymphatic vessels from the knee-joint together with those which accompany the genicular arteries. The remainder lie at the sides of the popliteal vessels, and receive as afferents the trunks which accompany the anterior and posterior tibial vessels. The efferents of the popliteal lymph-glands pass almost entirely alongside the femoral vessels to the deep subinguinal lymph-glands, but a few may accompany the great saphenous vein, and end in the superficial subinguinal lymph-glands.

Fig. 764.—The superficial lymph-glands and lymphatic vessels of the lower extremity.



The **inguinal lymph-glands** (fig. 764), from twelve to twenty in number, are situated at the upper part of the femoral triangle. They may be divided into two groups by a line drawn horizontally at the level of the termination of the great saphenous vein; those lying above this line are termed the superficial inguinal lymph-glands, and those below it the subinguinal lymph-glands, the latter group consisting of a superficial and a deep set.

The *superficial inguinal lymph-glands* form a chain immediately below the inguinal ligament. They receive as afferents the lymphatic vessels from the skin of the penis, scrotum (but not from the testis), perinæum, buttock, and abdominal wall below the level of the umbilicus; they also receive lymphatic vessels from the anal canal and from the mucous membrane of the anterior part of the urethra. In the female they receive the lymphatics from the vulva.

The *superficial subinguinal lymph-glands* are placed on either side of the upper part of the great saphenous vein; their afferents consist chiefly of the superficial lymphatic vessels of the lower extremity, except the back and lateral side of the calf of the leg, but they also receive some of the vessels which drain the skin of the penis, scrotum, perinæum, and buttock.

The *deep subinguinal lymph-glands* vary from one to three in number, and are placed deep to the fascia lata, on the medial side of the femoral vein. When three are present, the lowest is situated just below the junction of the great saphenous and femoral veins, the middle in the femoral canal, and the highest in the lateral part of the femoral ring. The middle one is the most inconstant, but the highest, the *lymph-gland of Cloquet or Rosenmüller*, is also frequently absent. They receive as afferents the deep lymphatic vessels which accompany the femoral vessels, the lymphatic vessels from the glans penis (or glans clitoridis), and also some of the efferents from the superficial subinguinal lymph-glands; their efferents pass through the femoral canal to the external iliac lymph-glands.

Applied Anatomy.—Inflammation and suppuration of the popliteal lymph-glands are most commonly due to a sore on the lateral side of the heel.

The inguinal and subinguinal lymph-glands frequently become enlarged in diseases

implicating the parts from which their lymphatic vessels originate. Thus in malignant or syphilitic affections of the prepuce and penis, or labia majora, in cancer of the scrotum, in abscess in the perinæum, anus and lower part of the vagina, or in similar diseases affecting the skin and superficial structures in those parts, or the subumbilical part of the abdominal wall, or the glutæal region, the upper group of lymph-glands is almost invariably enlarged, the lower groups being implicated in diseases affecting the lower limb.

THE LYMPHATIC VESSELS OF THE LOWER EXTREMITY

The *lymphatic vessels of the lower extremity* consist of two sets, superficial and deep, and in their distribution correspond closely with the veins.

The *superficial lymphatic vessels* lie in the superficial fascia, and are divisible into two groups: a medial, which follows the course of the great saphenous vein; and a lateral, which accompanies the small saphenous vein. The vessels of the *medial group* (fig. 764) are larger and more numerous than those of the lateral group, and commence on the tibial side and dorsum of the foot; they ascend in front of and behind the medial malleolus, run up the leg with the great saphenous vein, pass with it behind the medial condyle of the femur, and accompany it to the groin, where they end in the superficial subinguinal lymph-glands. The vessels of the *lateral group* arise from the fibular side of the foot; some ascend in front of the leg, and cross the tibia below the knee to join the lymphatics on the medial side of the thigh; others pass behind the lateral malleolus, and, accompanying the small saphenous vein, enter the popliteal lymph-glands.

The *deep lymphatic vessels* are few in number, and accompany the deep blood-vessels. In the leg, they consist of three sets, anterior tibial, posterior tibial, and peronæal, which accompany the corresponding blood-vessels, two or three with each artery; they enter the popliteal lymph-glands.

The deep lymphatic vessels of the glutæal and ischial regions follow the course of the corresponding blood-vessels. Those accompanying the superior glutæal vessels end in a lymph-gland which lies on the intrapelvic portion of the superior glutæal artery, near the upper border of the greater sciatic foramen. Those following the inferior glutæal vessels traverse one or two small lymph-glands which lie below the Piriformis muscle, and end in the hypogastric lymph-glands.

THE LYMPH-GLANDS OF THE ABDOMEN AND PELVIS

The **lymph-glands of the abdomen and pelvis** may be divided, from their situations, into: 1. *parietal*, lying behind the peritoneum and in close association with the larger blood-vessels; and 2. *visceral*, which are found in relation to the visceral arteries.

1. The **parietal lymph-glands** (figs. 765, 766) include the following groups:

External iliac.	Iliac circumflex.	Lumbar	Lateral aortic.
Common iliac.	Hypogastric.		Pre-aortic.
Inferior epigastric.	Sacral.		Retro-aortic.

The **external iliac lymph-glands,** from eight to ten in number, lie along the external iliac vessels. They are arranged in three groups, one on the lateral, another on the medial, and a third on the anterior aspect of the vessels; the third group is, however, sometimes absent. Their principal afferents are derived from the inguinal and subinguinal lymph-glands, the deep lymphatic vessels of the abdominal wall below the umbilicus and of the adductor region of the thigh, and the lymphatic vessels from the glans penis vel clitoridis, the membranous urethra, the prostate, the fundus of the urinary bladder, the cervix uteri, and upper part of the vagina.

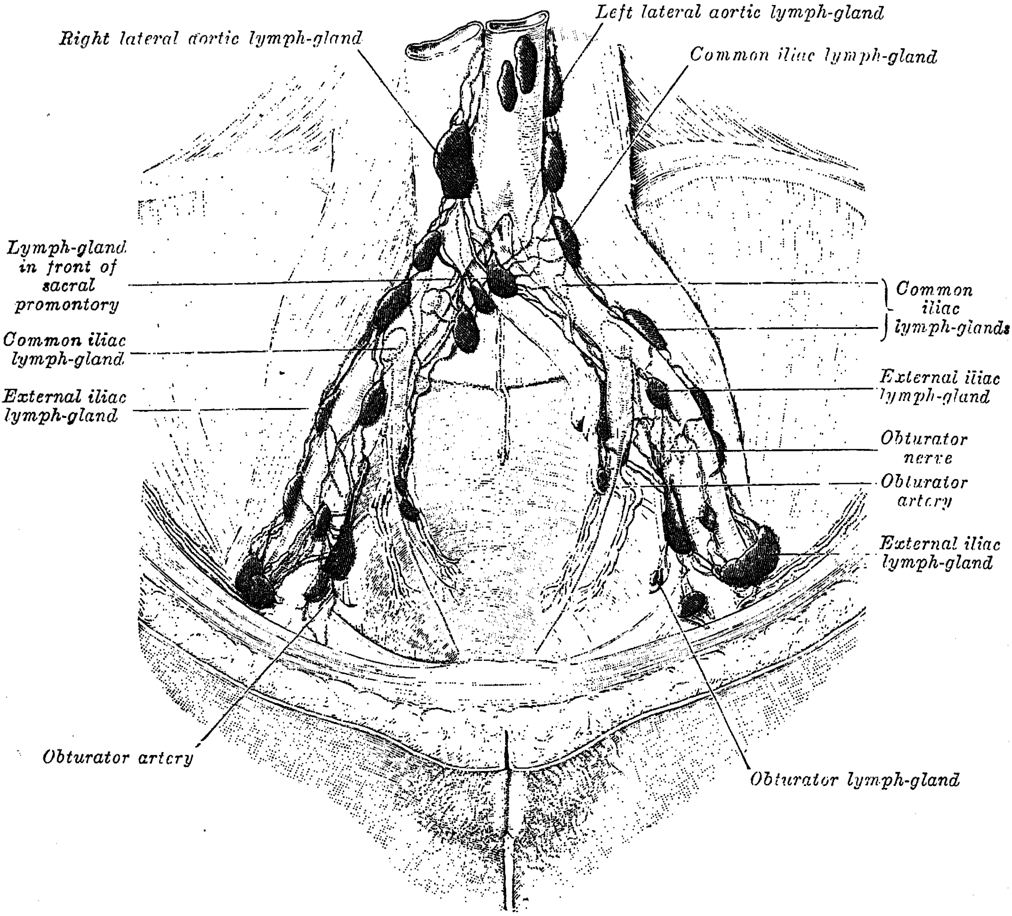
The **common iliac lymph-glands,** four to six in number, are grouped behind and on the sides of the common iliac artery, one or two (subaortic) being placed

below the bifurcation of the aorta, in front of the fifth lumbar vertebra. They drain chiefly the hypogastric and external iliac lymph-glands, and their efferents pass to the lateral aortic lymph-glands.

The **inferior epigastric lymph-glands,** three or four in number, are placed alongside the lower portions of the inferior epigastric vessels.

The **iliac circumflex lymph-glands,** two to four in number, lie along the course of the deep iliac circumflex vessels; they are sometimes absent.

FIG. 765.—The parietal lymph-glands of the pelvis. (Cunéo and Marcille.)



The **hypogastric lymph-glands** (fig. 766) surround the hypogastric vessels, and receive the lymphatic vessels corresponding to the distribution of the branches of the hypogastric artery, i.e. they receive lymphatic vessels from all the pelvic viscera, from the deeper parts of the perinæum, including the membranous and cavernous portions of the urethra, and from the buttock and back of the thigh. An *obturator lymph-gland* is sometimes present in the upper part of the obturator foramen.

The **sacral lymph-glands** are placed in the concavity of the sacrum, in relation to the middle and lateral sacral arteries; they receive lymphatic vessels from the rectum and posterior wall of the pelvis.

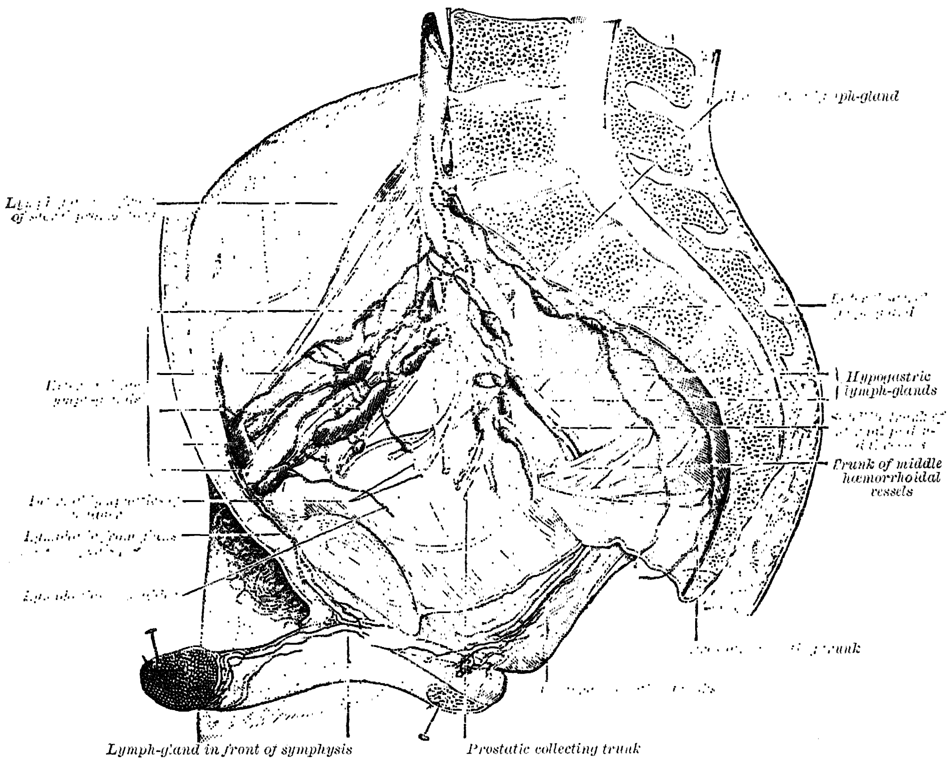
The efferents of the hypogastric and sacral groups end in the common iliac lymph-glands.

The **lumbar lymph-glands** are very numerous, and consist of right and left lateral aortic, pre-aortic, and retro-aortic groups.

The *right lateral aortic lymph-glands* are situated partly in front of the inferior vena cava, near the termination of the renal vein, and partly behind

it on the origin of the Psoas major, and on the right crus of the Diaphragm. The *left lateral aortic lymph-glands* form a chain on the left side of the abdominal aorta in front of the origin of the Psoas major and left crus of the Diaphragm. The lymph-glands on either side receive (*a*) the efferents of the common iliac lymph-glands; (*b*) the lymphatics from the testis in the male and from the ovary, uterine tube, and body of the uterus in the female; (*c*) the lymphatics from the kidney and suprarenal gland; and (*d*) the lymphatics draining the lateral abdominal muscles and accompanying the lumbar veins. Most of the efferent vessels of the lateral aortic lymph-glands converge to form the *right and left lumbar trunks* which join the cisterna chyli, but some enter the

Fig. 766.—The iliopelvic lymph-glands. (Cunéo and Marcille.)



pre- and retro-aortic lymph-glands, and others pierce the crura of the Diaphragm to join the lower end of the thoracic duct. The *pre-aortic lymph-glands* lie in front of the aorta, and may be divided into *cœliac*, *superior mesenteric*, and *inferior mesenteric* groups, arranged around the origins of the corresponding arteries. They receive a few vessels from the lateral aortic lymph-glands, but their principal afferents are derived from the viscera supplied by the three arteries with which the glands are associated. Some of their efferents pass to the retro-aortic lymph-glands, but the majority unite to form the *intestinal trunk*, which enters the cisterna chyli. The *retro-aortic lymph-glands* are placed below the cisterna chyli, on the bodies of the third and fourth lumbar vertebræ. They receive lymphatic vessels from the lateral and pre-aortic lymph-glands, while their efferents end in the cisterna chyli.

2. The visceral lymph-glands are associated with the branches of the cœliac, and superior and inferior mesenteric arteries. Those related to the branches of the cœliac artery form three sets, gastric, hepatic, and pancreaticolienal.

The gastric lymph-glands (figs. 767, 768) consist of two sets, superior and inferior.

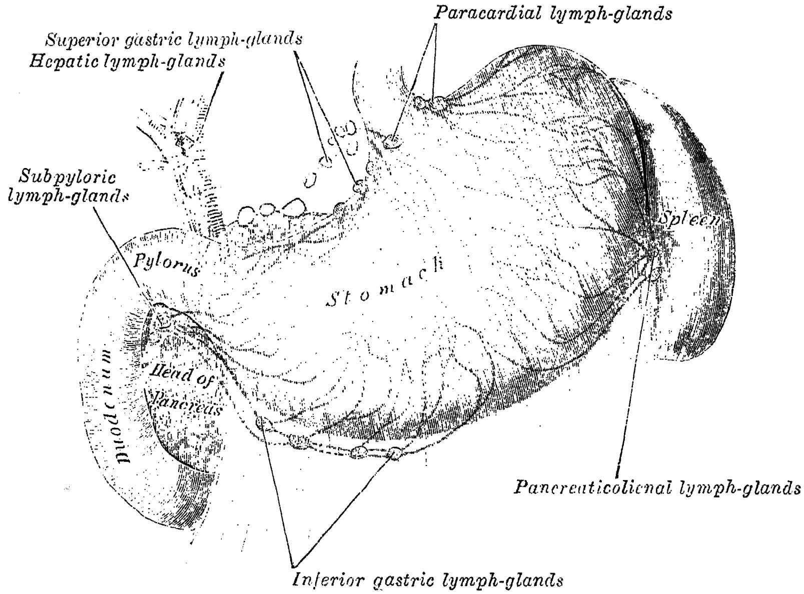
The **superior gastric lymph-glands** accompany the left gastric artery and are divisible into three groups, viz.: (*a*) *upper*, on the stem of the artery; (*b*) *lower*,

accompanying the descending branches of the artery along the cardiac half of the lesser curvature of the stomach, between the two layers of the lesser omentum; and (c) *paracardial*, disposed in a manner comparable to a chain of beads around the neck of the stomach (Jamieson and Dobson).* They receive their afferents from the stomach, and also some vessels from the pylorus; their efferents pass to the cœliac group of pre-aortic lymph-glands.

The **inferior gastric lymph-glands**, four to seven in number, lie between the two layers of the greater omentum along the pyloric half of the greater curvature of the stomach. They receive afferents from the stomach; their efferents mostly pass to the subpyloric lymph-glands.

The **hepatic lymph-glands** (fig. 767) consist of the following groups: (*a*) *hepatic*, on the stem of the hepatic artery, and extending upwards along the bile-duct, between the two layers of the lesser omentum, as far as the porta hepatis; one member of this group, the *cystic lymph-gland*, is placed near

FIG. 767.—The lymphatics of the stomach, &c. (Jamieson and Dobson.)



the neck of the gall-bladder; (*b*) *subpyloric*, four or five in number, in close relation to the bifurcation of the gastroduodenal artery, in the angle between the superior and descending parts of the duodenum; an outlying member of this group is sometimes found above the duodenum on the right gastric (pyloric) artery. The lymph-glands of the hepatic chain receive afferents from the stomach, duodenum, liver, gall-bladder, and pancreas; their efferents join the cœliac group of pre-aortic lymph-glands.

The **pancreaticolienal lymph-glands** (fig. 768) accompany the lienal (splenic) artery, and are situated in relation to the posterior surface and upper border of the pancreas; one or two members of this group are found in the gastrolienal ligament (Jamieson and Dobson, *loc. cit.*). Their afferents are derived from the stomach, spleen, and pancreas; their efferents join the cœliac group of pre-aortic lymph-glands.

The **superior mesenteric lymph-glands** may be divided into three principal groups: mesenteric, ileocolic, and mesocolic.

The *mesenteric lymph-glands* lie between the layers of the mesentery. They vary from one hundred to one hundred and fifty in number, and consist of three sets, viz.: one lying close to the wall of the small intestine, amongst the terminal twigs of the superior mesenteric artery; a second, in relation

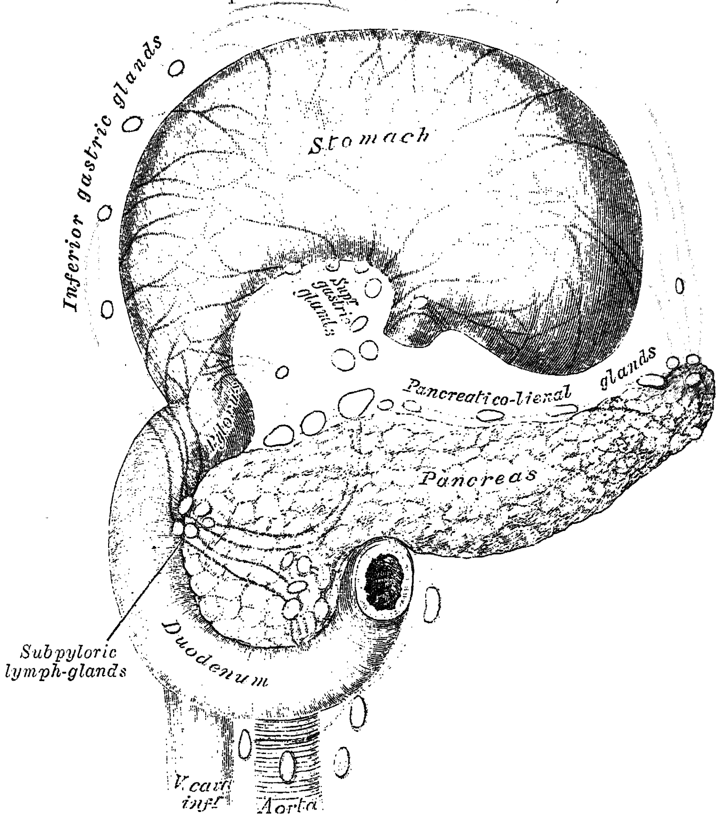
* J. K. Jamieson and J. F. Dobson, *Lancet*, April 20 and 27, 1907.

to the loops and primary branches of the jejunal and ileal vessels; and a third along the upper part of the trunk of the superior mesenteric artery.

Applied Anatomy.—Enlargement of the mesenteric lymph-glands is seen in most diseased conditions of the intestinal tract, and is well marked in enteric fever, tuberculous ulceration or malignant growths of the bowel. The enlarged lymph-glands can often be palpated through the wall of the abdomen.

The *ileocolic lymph-glands* (figs. 769, 770), from ten to twenty in number, form a chain around the ileocolic artery, but show a tendency to subdivision into two groups, one near the duodenum and another on the lower part of

FIG. 768.—The lymphatics of the stomach, &c. The stomach has been turned upwards. (Jamieson and Dobson.)



the trunk of the artery. Where the vessel divides into its terminal branches the chain is broken up into several groups, viz.: (*a*) *ileal*, in relation to the ileal branch of the artery; (*b*) *anterior ileocolic*, usually of three glands, in the ileocolic fold, near the wall of the cæcum; (*c*) *posterior ileocolic*, mostly placed in the angle between the ileum and the colon, but partly lying behind the cæcum at its junction with the ascending colon; (*d*) a single gland in the mesenteriole of the vermiform process; (*e*) *right colic*, along the medial side of the ascending colon.

The *mesocolic lymph-glands* are numerous, and lie between the layers of the transverse mesocolon, in close relation to the transverse colon; they are best developed in the neighbourhood of the right and left colic flexures. One or two small lymph-glands are occasionally seen along the trunk of the right colic artery, and others are found in relation to the trunk and branches of the middle colic artery.

The superior mesenteric lymph-glands receive afferents from the jejunum, ileum, cæcum, vermiform process, and the ascending and transverse parts of the

front of the transverse processes of the lumbar vertebræ, and is called the *ascending lumbar vein* ; it forms the most frequent origin of the corresponding azygos or hemiazygos vein, and serves to connect the common iliac, iliolumbar, and azygos or hemiazygos veins of its own side of the body.

The **testicular veins** (spermatic veins) (fig. 695) emerge from the back of the testis, and receive tributaries from the epididymis ; they unite and form a convoluted plexus, called the *pampiniform plexus* which constitutes the greater mass of the spermatic cord and ascends along the cord, in front of the ductus deferens. Below the subcutaneous inguinal ring the veins of the plexus unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the abdominal inguinal ring, coalesce to form two veins, which run upwards in front of the Psoas major and the ureter, behind the peritoneum, lying one on either side of the testicular artery. These two veins join to form a single vessel, which opens on the right side into the inferior vena cava at an acute angle ; on the left side into the left renal vein at a right angle. The testicular veins are provided with valves.* The left vein passes behind the iliac part of the descending colon and the lower margin of the pancreas, the right behind the terminal part of the ileum and the inferior part of the duodenum.

Applied Anatomy.—The testicular veins are very frequently varicose, constituting the condition known as *varicocele*. Varicocele almost invariably occurs on the left side, and this has been accounted for by the facts that the left testicular vein joins the left renal at a right angle; that it is overlaid by the iliac part of the descending colon, and that when this portion of the gut is full of fæcal matter, in cases of constipation, its weight impedes the return of the venous blood.

The operation for the removal of a varicocele consists in making a small incision just over the subcutaneous inguinal ring; the cord is lifted out and the spermatic fasciæ incised; the plexus of veins is then isolated from the ductus deferens and ligatured above and below, as high and as low as possible, and the intermediate portion cut away; the divided ends are fixed together with a suture, and the skin wound closed. The venous return is subsequently carried out by the small veins of the ductus deferens, of the Cremaster and those connecting with the scrotal tissues. In removing a varicocele the testicular artery is generally removed at the same time.

The **ovarian veins** in the female correspond with the testicular veins in the male ; each forms a plexus between the layers of the broad ligament near the ovary and uterine tube, and communicates with the uterine plexus. Two veins issue from this plexus and ascend in front of the external iliac artery, one lying on either side of the ovarian artery. Their further course and their mode of termination are the same as those of the testicular veins. Valves are occasionally found in the ovarian veins. Like the uterine veins, they become much enlarged during pregnancy.

The **renal veins**, of large size, are placed in front of the renal arteries, and almost at right angles to the inferior vena cava. The left is thrice the length of the right (7·5 cm. to 2·5 cm.), and passes in front of the aorta, just below the origin of the superior mesenteric artery. It receives the left testicular (or ovarian) vein, and one of the left inferior phrenic veins, and, generally, the left suprarenal vein. It opens into the inferior vena cava at a slightly higher level than the right.

The **suprarenal veins** are two in number : the right ends in the inferior vena cava ; the left usually in the left renal.

The **inferior phrenic veins** follow the course of the inferior phrenic arteries on the Diaphragm ; the right ends in the inferior vena cava ; the left is often represented by two branches, one of which ends in the left renal or suprarenal vein, while the other passes in front of the œsophageal hiatus in the Diaphragm and opens into the inferior vena cava.

The **hepatic veins** drain the liver, and commence in the *intralobular veins* which receive the blood from the sinusoids of the liver lobules. The intralobular veins open into the *sublobular veins*, and these in turn unite to form the hepatic veins which open into that portion of the inferior vena cava which

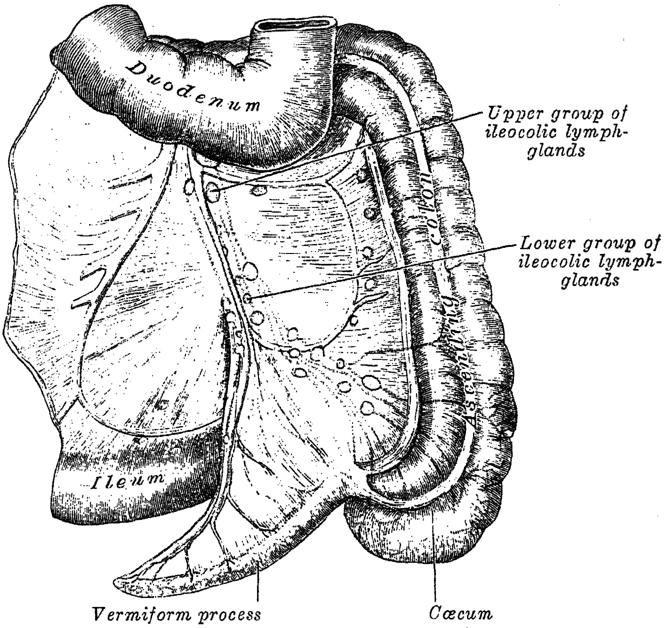
* Rivington has pointed out that valves are usually found at the orifices of both the right and left testicular veins. When, however, valves are not found at the opening of the left testicular vein into the left renal vein, they are generally present in the left renal vein within 6 mm. from the orifice of the testicular vein.—*Journal of Anatomy and Physiology*, vol. vii. p. 163.

and obturator vessels, follow the course of the hypogastric artery, and ultimately join the lateral aortic lymph-glands.

The *lymphatic vessels of the perinæum and external genitals.*—The lymphatic vessels of the perinæum, of the skin of the penis, and of the scrotum (or vulva) follow the course of the external pudendal vessels, and end in the superficial inguinal and subinguinal lymph-glands. Those of the glans penis (vel clitoridis) terminate partly in the deep subinguinal lymph-glands and partly in the external iliac lymph-glands.

2. The **visceral lymphatic vessels** consist of: (1) those of the subdiaphragmatic portion of the digestive tube and its associated glands, the liver and pancreas; (2) those of the spleen and suprarenal glands; (3) those of the urinary organs; (4) those of the reproductive organs.

FIG. 770.—The lymphatics of the cæcum and vermiform process. Posterior aspect. (Jamieson and Dobson.)



(1) The *lymphatic vessels of the subdiaphragmatic portion of the digestive tube* are situated partly in the submucous tissue and partly in the seromuscular coats, but as the former system drains into the latter, the two may be considered as one.

The *lymphatic vessels of the stomach* (figs. 767, 768) are continuous at the cardiac orifice with those of the œsophagus, and at the pylorus with those of the duodenum. They mainly follow the blood-vessels, and may be arranged in four sets. The first set accompanies the branches of the left gastric artery, receives tributaries from a large area on both surfaces of the stomach, and terminates in the superior gastric lymph-glands. Those of the second set drain the fundus and body of the stomach on the left of a line drawn vertically from the œsophagus; they accompany, more or less closely, the short gastric and left gastro-epiploic arteries. and end in the pancreaticolienal lymph-glands. The third set drains the right part of the greater curvature as far as the pyloric portion, and ends in the inferior gastric lymph-glands, the efferents of which pass to the subpyloric group. Those of the fourth set drain the pyloric portion and pass to the hepatic, subpyloric, and superior gastric lymph-glands.

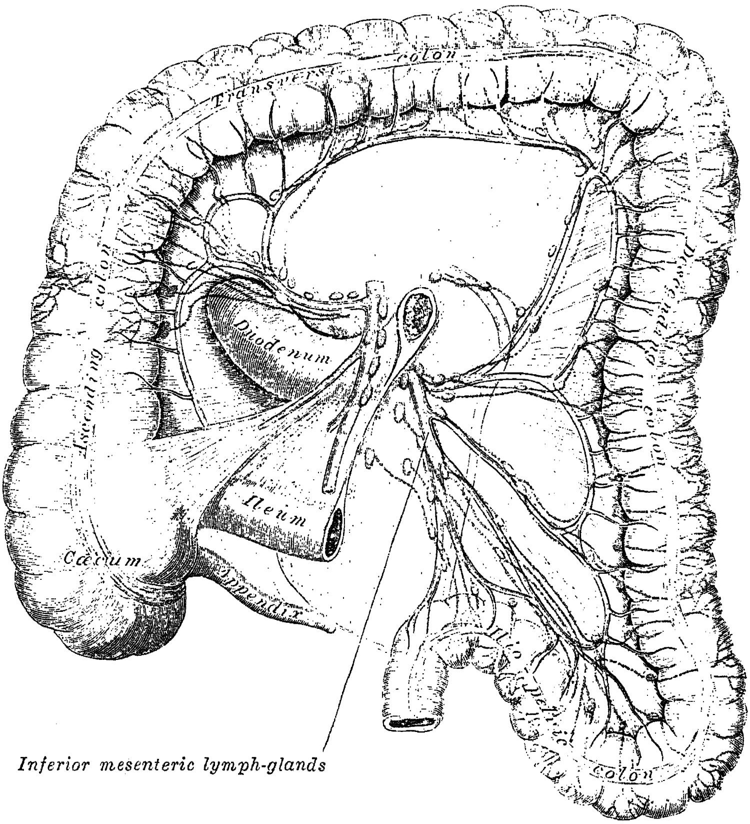
The *lymphatic vessels of the duodenum* consist of an anterior and a posterior set, which open into a series of small *pancreaticoduodenal lymph-glands,* on the anterior and posterior aspects of the groove between the head of the pancreas

and the duodenum. The efferents of these glands run in two directions, upwards to the hepatic lymph-glands, and downwards to the pre-aortic lymph-glands around the origin of the superior mesenteric artery.

The *lymphatic vessels of the jejunum and ileum* are termed *lacteals*, from the milk-white fluid they contain during intestinal digestion. They run between the layers of the mesentery and enter the mesenteric glands, the efferents from which end in the pre-aortic lymph-glands.

The *lymphatic vessels of the vermiform process and cæcum* (figs. 769, 770) are numerous, since in the wall of the vermiform process there is a large amount of lymphoid tissue. From the body and tail of the vermiform process eight to

Fig. 771.—The lymphatics of the colon. (Jamieson and Dobson.)



fifteen vessels ascend between the layers of the mesenteriole, one or two being interrupted in the lymph-gland which lies between the layers of this peritoneal fold. They unite to form three or four vessels, which end partly in the lower and partly in the upper lymph-glands of the ileocolic chain. The vessels from the root of the vermiform process and from the cæcum consist of an anterior and a posterior group. The anterior vessels pass in front of the cæcum, and end in the anterior ileocolic lymph-glands and in the upper and lower lymph-glands of the ileocolic chain; the posterior vessels ascend over the back of the cæcum and terminate in the posterior ileocolic lymph-glands and in the lower lymph-glands of the ileocolic chain.

Lymphatic vessels of the colon (fig. 771).—The lymphatic vessels of the ascending and transverse parts of the colon end in the mesenteric lymph-glands, after traversing the right colic and mesocolic lymph-glands. Those of the descending and sigmoid parts of the colon are interrupted by the small lymph-glands on the branches of the left colic and sigmoid arteries, and ultimately end in the pre-aortic lymph-glands around the origin of the inferior mesenteric artery.

common iliac veins by the ascending lumbar veins, and with many of the tributaries of the inferior vena cava.

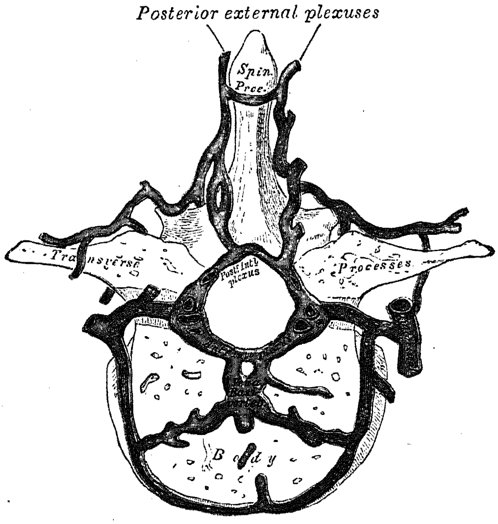
Thrombosis of the superior vena cava is oftenest due to pressure exerted on the vessel by an aneurysm or a tumour; it may also occur by propagation of clotting from a tributary peripheral vein. If occlusion of the vessel take place slowly, a collateral venous circulation may be established; the patient will have some œdema with dilatation and congestion of the veins about the head and neck, and may also suffer from attacks of dyspnœa and recurrent pleural effusion. In most cases, however, the blockage of the superior cava takes place rapidly, and is rapidly fatal.

The **bronchial veins**, usually two on either side, return the blood from the larger bronchi, and from the structures at the roots of the lungs; those of the right side open into the terminal part of the vena azygos; those of the left side, into the left superior intercostal vein or the accessory hemiazygos vein. Some of the blood carried to the lungs through the bronchial arteries is returned to the heart through the pulmonary veins.

The Veins of the Vertebral Column (figs. 742, 743)

The veins which drain the blood from the vertebral column, the neighbouring muscles, and the meninges of the medulla spinalis form intricate plexuses extending along the entire length of the column; these plexuses are divisible into two groups, external and internal, according to their positions outside or inside the vertebral canal. The plexuses of the two groups anastomose freely with each other, and end in the intervertebral veins.

Fig. 742.—A transverse section through a thoracic vertebra, showing the vertebral venous plexuses.



The **external vertebral venous plexuses**, best marked in the cervical region, consist of anterior and posterior plexuses which anastomose freely with each other. The *anterior external plexuses* lie in front of the bodies of the vertebræ, communicate with the basivertebral and intervertebral veins, and receive tributaries from the vertebral bodies. The *posterior external plexuses* are placed partly on the posterior surfaces of the vertebral arches and their processes, and partly between the deep dorsal muscles. In the cervical region they anastomose with the vertebral, occipital, and deep cervical veins.

The **internal vertebral venous plexuses** lie within the vertebral canal between the dura mater and the vertebræ, and receive tributaries from the bones and from the medulla spinalis. They form a closer network than the external plexuses, and, running mainly in a vertical direction, form four longitudinal veins, two in front and two behind; they therefore may be divided into anterior and posterior groups. The *anterior internal plexuses* consist of large veins which lie on the posterior surfaces of the vertebral bodies and intervertebral fibrocartilages, on either side of the posterior longitudinal ligament; under cover of this ligament they are connected by transverse branches into which the basivertebral veins open. The *posterior internal plexuses* are placed one on either side of the middle line in front of the vertebral arches and ligamenta flava, and anastomose, by veins passing through those ligaments, with the posterior external plexuses.

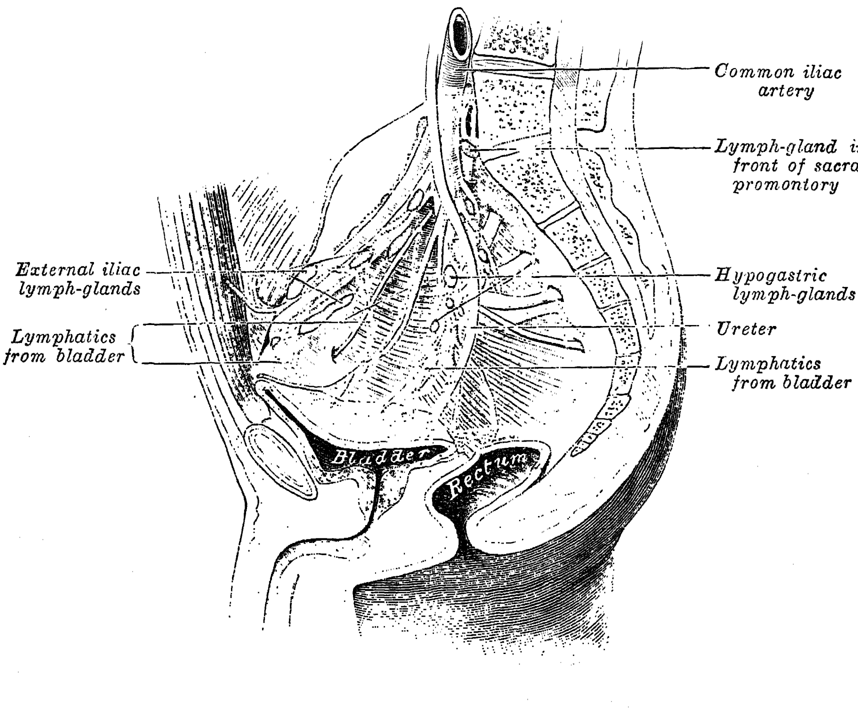
The anterior and posterior internal plexuses communicate freely with one another by a series of venous rings, one opposite each vertebra. Around the foramen magnum they form an intricate network which opens into the vertebral

The *lymphatic vessels of the kidney* form three plexuses: one in the substance of the kidney, a second beneath its fibrous capsule, and a third in the perinephric fat; the second and third communicate freely with each other.

The vessels from the plexus in the substance of the kidney converge to form four or five trunks which issue at the hilum. Here they are joined by vessels from the plexus under the capsule, and, following the course of the renal vein, end in the lateral aortic lymph-glands. The perinephric plexus is drained directly into the upper lateral aortic lymph-glands.

The *lymphatic vessels of the ureter* run in different directions. Those from its upper portion end partly in the efferent vessels from the kidney and partly in the lateral aortic lymph-glands; those from the portion immediately above the brim of the lesser pelvis are drained into the common iliac lymph-glands; while the vessels from the intrapelvic portion of the tube either join the efferents from the bladder, or end in the hypogastric lymph-glands.

FIG. 772.—The lymphatics of the urinary bladder. (Cunéo and Marcille.)



The *lymphatic vessels of the urinary bladder* (fig. 772) begin in two plexuses, an intra- and an extra-muscular, it being generally admitted that the mucous membrane is devoid of lymphatics.* The efferent vessels are arranged in two groups, one from the anterior and another from the posterior surface of the bladder. The vessels from the *anterior* surface pass to the external iliac lymph-glands, though there are also some minute lymph-glands distributed along the course of the vessels. These minute lymph-glands are arranged in two groups, an *anterior vesical*, in front of the bladder, and a *lateral vesical*, in relation to the lateral umbilical ligament. The vessels from the *posterior* surface pass to the hypogastric, external, and common iliac lymph-glands; those draining the upper part of this surface traverse the lateral vesical lymph-glands.

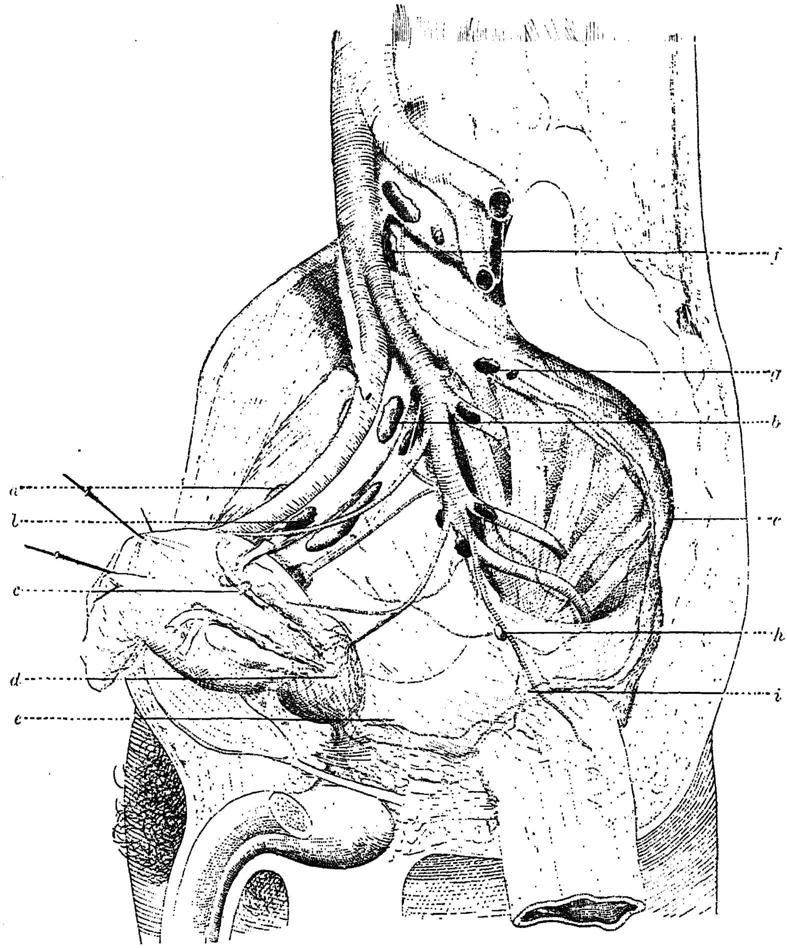
The *lymphatic vessels of the prostate* (fig. 773) terminate chiefly in the hypogastric and sacral lymph-glands, but one trunk from the posterior surface ends

* Some authorities maintain that a plexus of lymphatic vessels does exist in the mucous membrane of the bladder (consult *Médecine opératoire des Voies urinaires,* par J. Albarran. Paris, 1909).

in the external iliac lymph-glands, and another from the anterior surface joins the vessels which drain the membranous part of the urethra.

Lymphatic vessels of the urethra.—The lymphatics of the *cavernous* portion of the urethra accompany those of the glans penis, and end with them in the superficial and deep subinguinal and external iliac lymph-glands. Those of the *membranous* and *prostatic* portions, and those of the whole urethra in the female, pass to the hypogastric lymph-glands.

FIG. 773.—The lymphatics of the prostate. (Cunéo and Marcille.)



a, b. External iliac lymph-glands. *c.* Vessel draining into external iliac lymph-glands. *d.* Retro-prostatic lymph-glands. *e.* Vessels draining into lymph-gland on sacral promontory. *f.* Lymph-gland in front of sacral promontory. *g.* Lateral sacral lymph-glands. *h.* Middle hæmorrhoidal lymph-gland. *i.* Middle hæmorrhoidal lymphatic vessels.

(4) *The lymphatic vessels of the reproductive organs.*

The *lymphatic vessels of the testis* consist of two sets, superficial and deep, the former commencing on the surface of the tunica vaginalis, the latter in the epididymis and body of the testis. They form from four to eight collecting trunks which ascend with the testicular veins in the spermatic cord and along the front of the Psoas major, to end in the lateral and pre-aortic groups of lumbar lymph-glands.*

The *lymphatic vessels of the ductus deferens* pass to the external iliac lymph-glands; those of the *vesiculæ seminales* go partly to the hypogastric and partly to the external iliac lymph-glands.

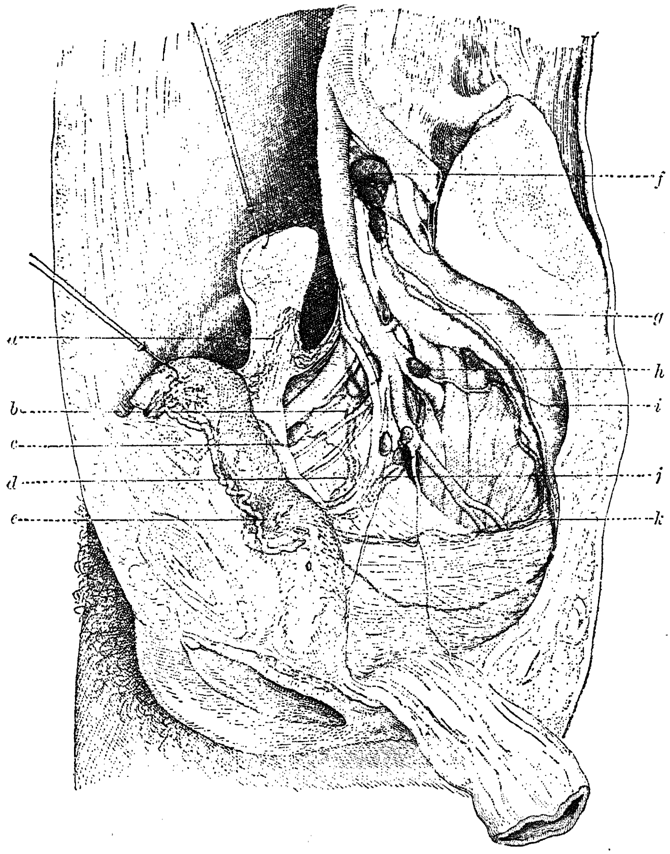
* 'The lymphatics of the testicle,' by J. K. Jamieson and J. F. Dobson, *Lancet*, Feb. 19, 1900.

The *lymphatic vessels of the ovary* are similar to those of the testis, and ascend with the ovarian artery to the lateral and pre-aortic lymph-glands.

The *lymphatic vessels of the uterine tube* pass partly with those of the ovary and partly with those of the uterus.

The *lymphatic vessels of the uterus* (fig. 774) consist of two sets, superficial and deep, the former being placed beneath the peritoneum, the latter in the substance of the organ. The lymphatics of the cervix uteri run in three directions: transversely to the external iliac lymph-glands, posterolaterally

FIG. 774.—The lymphatics of the uterus. (Cunéo and Marcille.)



a. Efferents to lateral aortic lymph-glands. *b*, *c*, *d*. Efferents to external iliac lymph-glands. *e*. Network on lateral aspect of cervix uteri. *f*. Lymph-glands in front of sacral promontory. *g*. Efferents to lymph-glands in front of sacral promontory. *h*. Hypogastric lymph-glands. *i*. Lateral sacral lymph-glands. *j*. Vessels draining into hypogastric lymph-glands. *k*. Vessels passing to lateral sacral lymph-glands.

to the hypogastric lymph-glands, and posteriorly to the common iliac lymph-glands. The majority of the vessels of the body and fundus of the uterus pass lateralwards in the upper parts of the broad ligaments, and ascend alongside the ovarian vessels to the lateral and pre-aortic lymph-glands; a few, however, run to the external iliac lymph-glands, and one or two run along the round ligament of the uterus to the superficial inguinal lymph-glands. In the unimpregnated uterus the lymphatic vessels are very small, but during gestation they are greatly enlarged.

The *lymphatic vessels of the vagina* are carried in three directions: those of the upper part to the external iliac lymph-glands, those of the middle part to the hypogastric lymph-glands, and those of the lower part to the common iliac lymph-glands. On the course of the vessels from the middle and lower parts small lymph-glands are situated. Some lymphatic vessels from the

lower part of the vagina join those of the vulva and pass to the superficial inguinal lymph-glands. The lymphatic vessels of the vagina anastomose with those of the cervix uteri, vulva, and rectum, but not with those of the bladder.

THE LYMPH-GLANDS OF THE THORAX

The **lymph-glands of the thorax** may be divided into: 1. parietal and 2. visceral—the former being situated in the thoracic wall, the latter in relation to the viscera.

1. The **parietal lymph-glands** include the sternal, intercostal, and diaphragmatic glands.

(*a*) The **sternal or internal mammary lymph-glands** are four or five in number on each side, and are placed (fig. 775) at the anterior ends of the intercostal spaces, by the side of the internal mammary artery.* They derive afferents from the mamma, from the deeper structures of the anterior abdominal wall above the level of the umbilicus, from the upper surface of the liver through a small group of lymph-glands which lies behind the xiphoid process, and from the deeper parts of the anterior portion of the thoracic wall. Their efferents usually unite to form a single trunk on either side; this may open directly into the junction of the internal jugular and subclavian veins, or that of the right side may join the right subclavian trunk, and that of the left the thoracic duct.

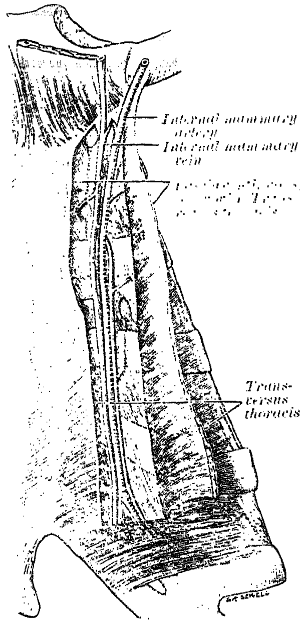


Fig. 775.—The right sternal or internal mammary lymph-glands (E. P. Stibbe).

(*b*) The **intercostal lymph-glands** lie in the posterior parts of the intercostal spaces and in front of the heads of the ribs. They receive the deep lymphatics from the posterolateral aspect of the chest; some of these vessels are interrupted by small lateral intercostal lymph-glands. The efferents of the lymph-glands in the lower four or five spaces unite to form a trunk, which descends and opens either into the cisterna chyli or into the commencement of the thoracic duct. The efferents of the lymph-glands in the upper spaces of the left side end in the thoracic duct; those of the corresponding right spaces, in the right lymphatic duct.

(*c*) The **diaphragmatic lymph-glands** lie on the thoracic aspect of the Diaphragm, and consist of three sets, anterior, middle, and posterior.

The *anterior* set comprises (*a*) two or three small lymph-glands behind the base of the xiphoid process, which receive afferents from the convex surface of the liver, and (*b*) one or two lymph-glands on either side near the junction of the seventh rib with its cartilage, which receive lymphatic vessels from the front part of the Diaphragm. The efferent vessels of the anterior set pass to the sternal lymph-glands.

The *middle* set consists of two or three lymph-glands on either side close to where the phrenic nerves enter the Diaphragm. On the right side some of the lymph-glands of this group lie within the fibrous wall of the pericardium, on the front of the termination of the inferior vena cava. The afferents of this set are derived from the middle part of the Diaphragm, those on the right side also receiving afferents from the convex surface of the liver. Their efferents pass to the posterior mediastinal lymph-glands.

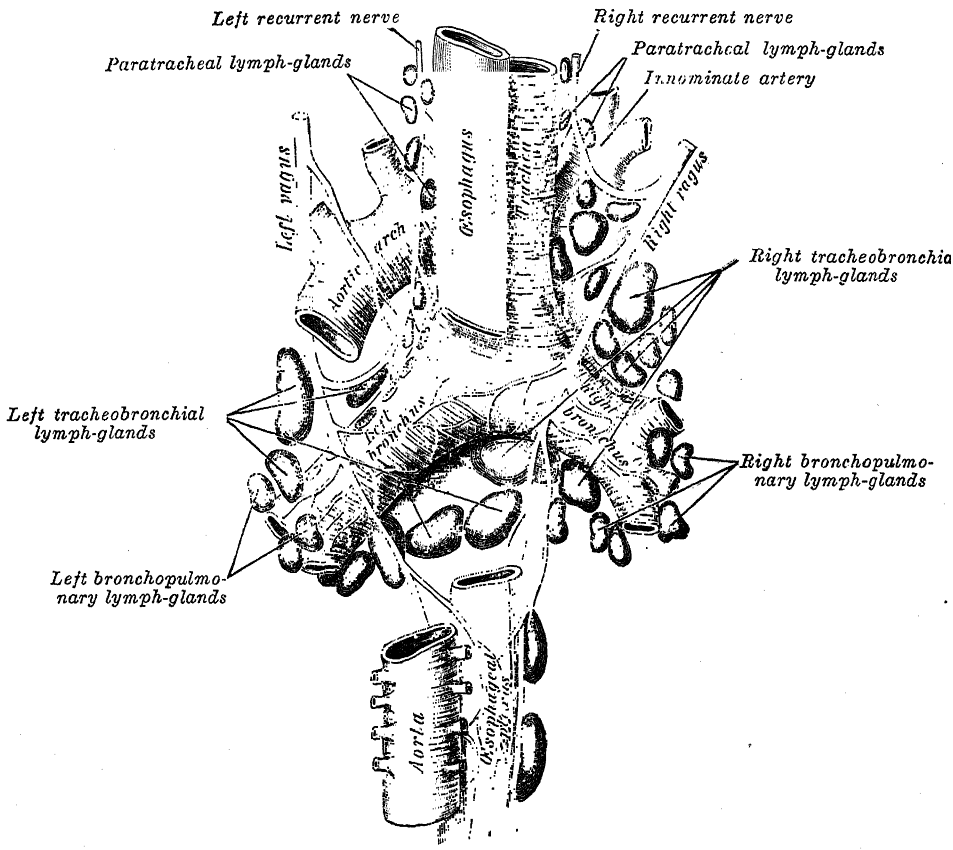
The *posterior* set consists of a few lymph-glands situated on the back of the crura of the Diaphragm, and connected on the one hand with the lumbar lymph-glands. and on the other with the posterior mediastinal lymph-glands.

* E. P. Stibbe, *Journal of Anatomy*, vol. 52.

2. The **visceral lymph-glands** consist of three groups, viz. anterior mediastinal, posterior mediastinal, and tracheobronchial.

The **anterior mediastinal lymph-glands** are placed in the anterior part of the superior mediastinal cavity, in front of the aortic arch and in relation to the innominate veins and the large arterial trunks which arise from the aortic arch. They receive afferents from the thymus and pericardium, and from the sternal lymph-glands; their efferents unite with those of the tracheobronchial lymph-glands, to form the right and left bronchomediastinal trunks.

Fig. 776.—The tracheobronchial lymph-glands. (From a figure designed by M. Hallé.)



The **posterior mediastinal lymph-glands** lie behind the pericardium in relation to the œsophagus and descending thoracic aorta. Their afferents are derived from the œsophagus, the posterior part of the pericardium, the Diaphragm, and the convex surface of the liver. Their efferents mostly end in the thoracic duct, but some join the tracheobronchial lymph-glands.

The **tracheobronchial lymph-glands** (fig. 776) form four main groups, and include some of the largest lymph-glands in the body: (*a*) *tracheal*, on either side of the trachea; (*b*) *bronchial*, in the angles between the lower part of the trachea and bronchi, and in the angle between the two bronchi; (*c*) *bronchopulmonary*, in the hilum of each lung; and (*d*) *pulmonary*, in the lung substance, on the larger branches of the bronchi. The afferents of the tracheobronchial lymph-glands drain the lungs and bronchi, the thoracic part of the trachea, and the heart; some of the efferents of the posterior mediastinal lymph-glands also end in this group. Their efferent vessels ascend upon the trachea and unite with efferents of the internal mammary and anterior mediastinal lymph-glands to form the *right* and *left bronchomediastinal trunks*. The right bronchomediastinal trunk may join the right lymphatic duct, and

the left the thoracic duct, but more frequently they open independently of these ducts into the junction of the internal jugular and subclavian veins of their own side.

Applied Anatomy.—In all town-dwellers there are continually being swept into these lymph-glands from the bronchi and alveoli large quantities of the dust and black carbonaceous pigment that are so freely inhaled in cities. At first the lymph-glands are moderately enlarged, firm, inky black and gritty on section; later they enlarge still further, often becoming fibrous from the irritation set up by the minute foreign bodies with which they are crammed, and may break down into a soft slimy mass or may calcify. In tuberculosis of the lungs these lymph-glands are practically always infected; they enlarge, being filled with tuberculous deposits that may soften, or become fibrous, or calcify. Not infrequently an enlarged tuberculous lymph-gland perforates into a bronchus, discharging its contents into the tube. When this happens there is great danger of acute pulmonary tuberculosis, the infecting gland-substance being rapidly spread throughout the bronchial system by the coughing its presence in the air-passages excites.

Tuberculous infection with considerable enlargement of the tracheobronchial glands is common in children. It produces a characteristic patch of impaired resonance on percussion, with increase in the vocal fremitus and resonance and harsh bronchial breath-sounds, over a diamond-shaped area on the back about the region of the third, fourth and fifth thoracic vertebral spines. It is thought, too, that enlargement of these glands produces an irritative dry cough in children, by pressure on the pulmonary nerves in their neighbourhood.

THE LYMPHATIC VESSELS OF THE THORAX

The lymphatic vessels of the thorax may be divided into: 1. those of the thoracic wall and 2. those of the thoracic viscera.

1. The *superficial lymphatic vessels of the thoracic wall* ramify beneath the skin and converge to the axillary lymph-glands. Those over the Trapezius and Latissimus dorsi run forwards and unite to form about ten or twelve trunks which end in the subscapular group. Those over the pectoral region, including the vessels from the skin covering the peripheral part of the mamma, run backwards, and those over the Serratus anterior upwards, to the pectoral group. Others near the lateral margin of the sternum pass inwards between the rib cartilages and end in the sternal lymph-glands, while the vessels of opposite sides anastomose across the front of the sternum. A few vessels from the upper part of the pectoral region ascend over the clavicle to the inferior deep cervical lymph-glands.

The *lymphatic vessels of the mamma* originate in a plexus in the interlobular spaces and on the walls of the galactophorous ducts. Those from the central part of the mamma pass to an intricate plexus situated beneath the areola, a plexus which receives also the lymphatics from the skin over the central part of the mamma and those from the areola and nipple. Its efferents are collected into two trunks which pass to the pectoral group of axillary lymph-glands. The vessels which drain the medial part of the mamma pierce the thoracic wall and end in the sternal lymph-glands, while a vessel occasionally emerges from the upper part of the mamma, and, piercing the Pectoralis major, terminates in the subclavicular lymph-glands (fig. 761).

The *deep lymphatic vessels of the thoracic wall* consist of:

(*a*) The lymphatic vessels of the muscles which lie on the ribs: most of these end in the axillary lymph-glands, but some from the Pectoralis major pass to the sternal lymph-glands. (*b*) The intercostal lymphatic vessels which drain the Intercostales and parietal pleura. Those draining the Intercostales externi run backwards and, after receiving the vessels which accompany the posterior branches of the intercostal arteries, end in the intercostal lymph-glands. Those of the Intercostales interni and parietal pleura consist of a single trunk in each space. These trunks run forwards in the subpleural tissue, and the upper six open separately into the sternal lymph-glands or into the vessels which unite them; while those of the lower spaces join to form a single trunk which terminates in the lowest of the sternal lymph-glands. (*c*) The lymphatic vessels of the Diaphragm, which form two plexuses, one on its thoracic and another on its abdominal surface; these plexuses anastomose freely with each other, and are best marked on the parts covered respectively by the pleuræ and

peritoneum. The plexus on the thoracic surface unites with the lymphatics of the costal and mediastinal parts of the pleura, and its efferents consist of three groups: anterior, passing to the lymph-glands which lie near the junction of the seventh rib with its cartilage; middle, to the lymph-glands on the œsophagus and to those around the termination of the inferior vena cava; and posterior, to the lymph-glands which surround the aorta at the point where this vessel leaves the thoracic cavity. The plexus on the abdominal surface is composed of fine vessels, and anastomoses with the lymphatics of the liver and, at the periphery of the Diaphragm, with those of the subperitoneal tissue. The efferents from the right half of this plexus terminate partly in a group of lymph-glands on the trunk of the corresponding inferior phrenic artery, while others end in the right lateral aortic lymph-glands. Those from the left half of the plexus pass to the pre-aortic and lateral aortic lymph-glands and to the lymph-glands on the terminal portion of the œsophagus.

2. The *lymphatic vessels of the thoracic viscera* comprise those of the heart and pericardium, lungs and pleura, thymus, and œsophagus.

The *lymphatic vessels of the heart* consist of two plexuses: (*a*) deep, immediately under the endocardium, and (*b*) superficial, subjacent to the visceral pericardium. The deep plexus opens into the superficial, the efferents of which form left and right collecting trunks. The *left* trunks, two or three in number, ascend in the anterior longitudinal sulcus, receiving, in their course, vessels from both ventricles. On reaching the coronary sulcus they are joined by a large trunk from the diaphragmatic surface of the heart, and then unite to form a single vessel which ascends between the pulmonary artery and the left atrium, and ends in one of the tracheobronchial lymph-glands. The *right* trunk receives its afferents from the right atrium and from the right border and diaphragmatic surface of the right ventricle. It ascends in the posterior longitudinal sulcus and then runs forward in the coronary sulcus, and passes up behind the pulmonary artery, to end in one of the tracheobronchial lymph-glands.

The *lymphatic vessels of the lungs* originate in two plexuses, a superficial and a deep. The superficial plexus is placed beneath the pulmonary pleura; the deep accompanies the branches of the pulmonary vessels and the ramifications of the bronchi. In the case of the larger bronchi the deep plexus consists of two networks—a submucous, beneath the mucous membrane, and a peribronchial, outside the walls of the bronchi. In the smaller bronchi there is but a single plexus, which extends as far as the bronchioles, but fails to reach the alveoli, in the walls of which there are no traces of lymphatic vessels. The superficial efferents turn round the borders of the lungs and the margins of their fissures, and converge to end in some lymph-glands situated at the hilum; the deep efferents are conducted to the hilum along the pulmonary vessels and bronchi, and end in the tracheobronchial lymph-glands. Little or no anastomosis occurs between the superficial and deep lymphatics of the lungs, except in the region of the hilum.

The *lymphatic vessels of the pleura* consist of two sets—one in the visceral and another in the parietal part of the membrane. Those of the visceral pleura drain into the superficial efferents of the lung, while those of the parietal pleura have three modes of ending, viz.: (*a*) those of the costal portion join the lymphatics of the Intercostales interni and so reach the sternal lymph-glands; (*b*) those of the diaphragmatic part are drained by the efferents of the Diaphragm; while (*c*) those of the mediastinal portion end in the posterior mediastinal lymph-glands.

The *lymphatic vessels of the thymus* end in the anterior mediastinal, tracheobronchial, and sternal lymph-glands.

The *lymphatic vessels of the œsophagus* form a plexus round that tube, and the collecting vessels from the plexus drain into the posterior mediastinal lymph-glands.

NEUROLOGY

THE **nervous system** is the most complicated and highly organised of the human body. It is built up of nervous and non-nervous tissues—the former consisting of nerve-cells and nerve-fibres, the latter of neuroglia and blood-vessels, together with certain enveloping membranes.

The minute structure of the nervous elements and neuroglia is described on pp. 32 to 39, and an outline of the development of the nervous system is given on pp. 85 to 100.

The nervous system can be resolved into two subsidiary systems, the cerebrospinal and the autonomic, which however are intimately intermingled.

The **cerebrospinal system** is composed of a central and a peripheral part. The *central part* consists of an upper expanded portion, the *encephalon* or *brain*, contained within the cranium, and a lower, elongated, cylindrical portion, the *medulla spinalis* or *spinal cord*, lodged in the upper part of the vertebral canal. The two portions are united at the level of the upper border of the atlas vertebra, and together constitute the *central nervous system* or *cerebrospinal axis*. The peripheral part consists of the cerebrospinal nerves which unite the central nervous system to the various parts of the body, and are associated with the functions of the special and general senses, and with the voluntary movements of the body. There are forty-three pairs of these nerves—twelve *cerebral*, attached to the brain, and thirty-one *spinal*, to the medulla spinalis. Three pairs of the cerebral nerves, viz. the olfactory, the optic, and the acoustic, are connected with special sense-organs, and differ somewhat in their arrangement from the others, as will be subsequently described. The other cerebral nerves and all the spinal nerves are composed of fibres which arise from nerve-cells situated either in the central nervous system or in ganglia on the roots of the nerves.

The **autonomic system** transmits impulses which govern the calibre of the blood-vessels, regulate the movements of the viscera and iris, stimulate the Arrectores pilorum and excite the secretory glands. Like the cerebrospinal system it consists of a central and a peripheral portion. The *central part* consists of groups of nerve-cells situated in certain regions of the central nervous system. The *peripheral part* is composed of fibres which arise from these nerve-cells, and emerge in certain of the cerebral and spinal nerves. The fibres of the autonomic system never run continuously from their origin in the central nervous system to their areas of distribution, but always end in ganglia; from the nerve-cells of these ganglia new fibres arise and pass to their areas of distribution without further interruption. Autonomic nerves, therefore, consist of (*a*) *preganglionic* fibres, usually medullated, which spring from cells in the central nervous system and end in ganglia, and (*b*) *postganglionic fibres*, usually non-medullated, arising from cells in these ganglia and passing to their areas of distribution. The autonomic system consists of two subsidiary systems, the parasympathetic and the sympathetic.

The *parasympathetic system* is found at the cranial and sacral ends of the autonomic system. The cranial parasympathetic fibres issue from groups of nerve-cells in the mid-brain and medulla oblongata, and run in the oculomotor, facial, glossopharyngeal, vagus and accessory cerebral nerves. The sacral parasympathetic fibres issue from cells in the sacral part of the medulla spinalis and run in the second, third and fourth sacral nerves to the nerve-plexuses of the pelvis.

The *sympathetic system* is represented by two chains of central ganglia, placed one on either side of the middle line of the vertebral column, and

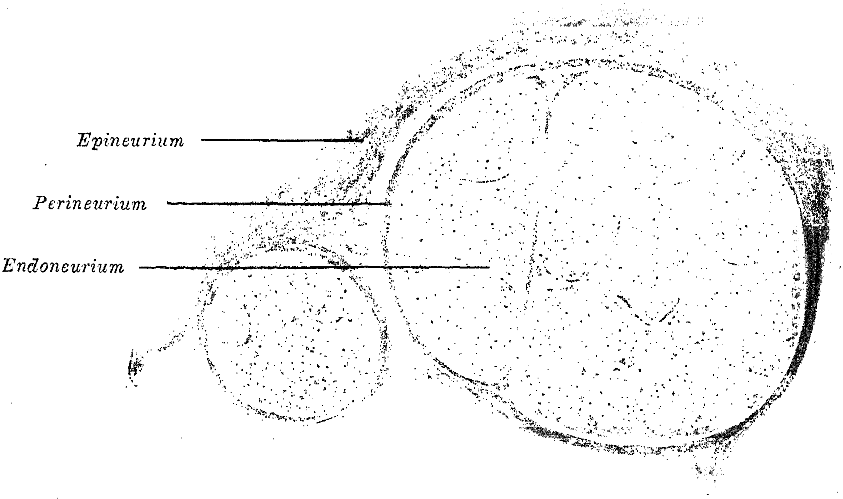
connected centrally with nerve-cells in the thoracic and lumbar parts of the medulla spinalis; from the cells of the central ganglia peripheral fibres run to form intricate plexuses, in many of which ganglia are found; from these plexuses the ultimate branches of distribution arise.

The chief involuntary structures, *e.g.* glands, viscera, etc., receive a double nerve-supply, parasympathetic and sympathetic, and these two systems are physiologically antagonistic; thus impulses through the parasympathetic fibres inhibit, while those through the sympathetic fibres accelerate, the movements of the heart; again impulses through the parasympathetic fibres contract, while those through the sympathetic fibres dilate, the pupil.

The Structure of the Peripheral Nerves and Ganglia

The **cerebrospinal nerves** consist of numerous nerve-fibres collected into bundles, which are enclosed in membranous sheaths (fig. 777); a small bundle of fibres is called a *funiculus*. Each funiculus is surrounded by a sheath, the *perineurium*;

Fig. 777.—A transverse section through two funiculi of a human tibial nerve. Stained with hæmatoxylin. ×30.



this consists of a fine, smooth, transparent membrane, made up of connective tissue, which has a lamellar arrangement; the sheath may be easily separated, in the form of a tube, from the fibres it encloses. The nerve-fibres are held together and supported within the funiculus by delicate connective tissue called the *endoneurium*; it is continuous with septa which pass inwards from the perineurium, and shows a ground substance in which are embedded fine bundles of fibrous connective tissue running for the most part longitudinally. If the nerve be small, it may consist of only a single funiculus; but if large, it consists of several funiculi held together and invested by connective tissue; this investment is known as the *epineurium*. The cerebrospinal nerves consist almost exclusively of medullated nerve-fibres, only a very small proportion of non-medullated fibres being present.

The blood-vessels supplying a nerve end in a minute plexus of capillaries which pierce the perineurium, and run, for the most part, parallel with the fibres; they are connected together by short, transverse vessels, forming narrow, oblong meshes, similar to the capillary system of muscle. Fine non-medullated nerve-fibres, *vasomotor fibres*, accompany these vessels, and break up into elementary fibrils which form a network around them. Medullated fibres, termed *nervi nervorum*, run in the epineurium and terminate in small spheroidal tactile corpuscles or end-bulbs of Krause.

The cerebrospinal nerve-fibres pursue an uninterrupted course from the centre to the periphery, but in separating a nerve into its component funiculi, it may be seen that bundles of fibres from one funiculus occasionally join, at a very acute angle, another funiculus proceeding in the same direction.

Nerves, in their course, subdivide into branches, and these frequently communicate with branches of neighbouring nerves; such communications form what is called a *nerve-plexus*. Sometimes a plexus is formed by the primary branches of the trunks of the nerves—as, for example, the cervical, brachial, lumbar, and sacral plexuses—and occasionally by the terminal funiculi, as in the plexuses formed at the periphery of the body. In the formation of a plexus, the component nerves divide, then join, and again subdivide in such a complex manner that the individual funiculi become intricately interlaced; so that each branch leaving a plexus may contain filaments from all the primary nervous trunks entering the plexus. In the formation also of smaller plexuses at the periphery of the body there is a free interchange of funiculi and fibres. In each case, however, the individual fibres remain separate and distinct.

Through this interchange of fibres, every nerve leaving a plexus gains a more extensive connexion with the medulla spinalis than if it had proceeded direct to its distribution without joining other nerves. Consequently the parts supplied by these nerves have more extended relations with the nervous centres; by this means also, groups of muscles may be associated for combined action.

The **autonomic nerves** consist largely of non-medullated fibres, collected in funiculi and enclosed in sheaths of connective tissue. There is, however, in these nerves a certain admixture of medullated fibres; thus, the cervical portions of the sympathetic trunk, and the splanchnic nerves contain many medullated preganglionic fibres.

The cerebrospinal and autonomic nerve-fibres convey various impressions. The *sensory* nerves, called also *centripetal* or *afferent* nerves, transmit to the nervous centres impressions made upon the peripheral ends of the nerves, and in this way the mind, through the medium of the brain, becomes conscious of external objects. The *centrifugal* or *efferent* nerves transmit impressions from the nervous centres to the parts to which they are distributed, these impressions either exciting muscular contraction, or influencing the process of secretion and possibly the processes of nutrition and growth.

Origins of nerves.—The origin of a nerve is in some cases single—that is to say, the whole nerve emerges from the nervous centre by a single root; in other instances the nerve arises by two or more roots. The point where the nerve-root or roots emerge from the surface of the nervous centre is named the *superficial* or *apparent* origin, but the fibres of the nerve can be traced to groups of nerve-cells in the grey substance of the nervous centre; these cell-groups constitute the *deep* or *real* origin of the nerve. The centrifugal or efferent nerve-fibres originate in the nerve-cells of the grey substance of the central nervous system, the axis-cylinder processes of these cells being prolonged to form the nerve-fibres. The centripetal or afferent nerve-fibres spring from nerve-cells in the organs of special sense (e.g. the retina) or from nerve-cells in the ganglia. Having entered the nerve-centre they branch and send their ultimate twigs among its cells, without, however, uniting with them.

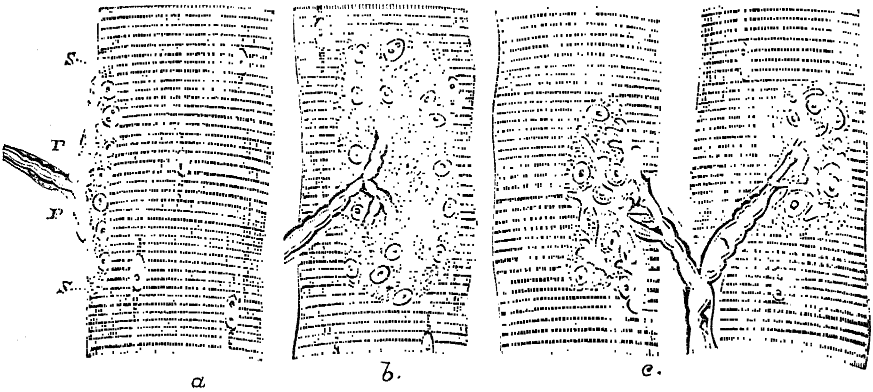
Peripheral terminations of nerves.—Nerve-fibres terminate peripherally in various ways, and these may be conveniently studied in the sensory and motor nerves respectively. The terminations of the sensory nerves are dealt with in the section on the sense-organs.

Motor nerves can be traced to either unstriped or striped muscular fibres. In the *unstriped or involuntary muscles* the nerves divide into numerous branches which communicate and form fine plexuses. At the junctions of the branches small nucleated bodies (ganglion-cells) are situated. From the plexuses minute branches are given off, which divide and break up into the ultimate fibrils of which the nerves are composed. These fibrils course between the involuntary muscle-cells, and, according to Elischer, terminate on the surface of the cells, opposite the nuclei, in minute swellings.

In the *striped or voluntary muscle* the nerves enter the sheath of the muscle, break up into fibres or bundles of fibres which form plexuses, and gradually divide until, as a rule, a single nerve-fibre enters a single muscular fibre; if the muscular fibre be long, more than one nerve-fibre may enter it. Within the muscular fibre

the nerve ends in a special expansion, called by Kühne, who first described it accurately, a *motor end-plate* (fig. 778). The nerve-fibre, on approaching the muscular fibre, suddenly loses its medullary sheath, the neurolemma becomes continuous with the sarcolemma of the muscle, and only the axis-cylinder enters

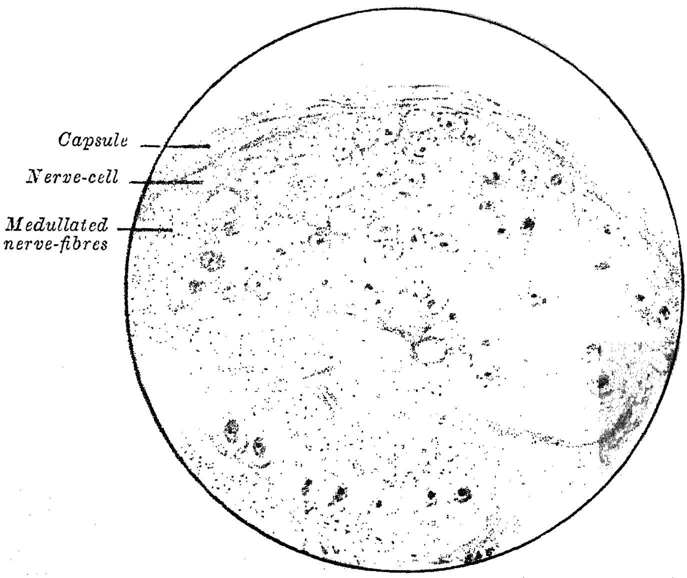
FIG. 778.—Muscular fibres of *Lacerta viridis* with the terminations of nerves.



a. Seen in profile. P.P. The motor end-plate. S.S. The base of the plate, consisting of a granular mass with nuclei. *b*. The same as seen in looking at a perfectly fresh fibre, the nerve-ends being probably still excitable. (The forms of the variously divided plate can hardly be represented in a woodcut by sufficiently delicate and pale contours to reproduce correctly what is seen in Nature.) *c*. The same as seen two hours after death from poisoning by curare.

the muscular fibre. There it ramifies immediately beneath the sarcolemma, and becomes imbedded in a layer of granular matter, containing a number of clear, oblong nuclei, the whole constituting a motor end-plate from which the contractile wave of the muscular fibre is said to start.

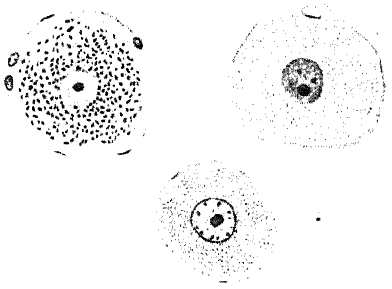
FIG. 779.—A transverse section through a human spinal ganglion. Stained with methyl blue. Note the brown pigment in some of the ganglion cells. ×60.



Ganglia are small aggregations of nerve-cells. They are found on the posterior roots of the spinal nerves; on the sensory roots of the trigeminal, facial, glossopharyngeal, and vagus nerves, and on the acoustic nerves. They are also found in connexion with the sympathetic nerves. They consist of a reddish-grey

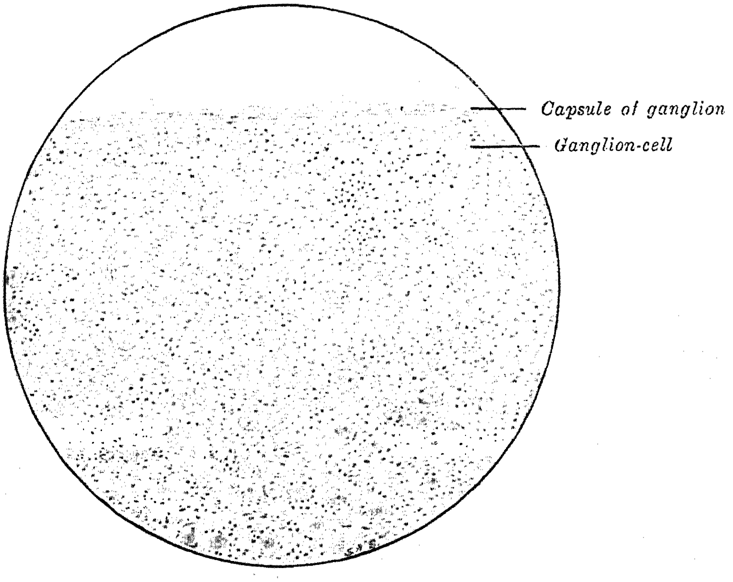
substance, traversed by numerous white nerve-fibres, and vary considerably in form and size; the largest are found in the cavity of the abdomen; the smallest, not visible to the naked eye, exist in considerable numbers upon the nerves distributed to the viscera. Each ganglion is invested by a smooth, firm, membranous envelope, consisting of dense areolar tissue; this envelope is continuous with the perineurium of the nerves, and sends numerous processes into the interior of the ganglion.

FIG. 780.—Three types of nerve-cells from a spinal ganglion of a cat. Stained with hæmatoxylin and eosin. × 350. (The nuclei of the cells lining the capsule are shown in the left-hand figure only.)



Ganglia consist of nerve-cells and nerve-fibres. Each nerve-cell has a nucleated capsule which is continuous with the neurolemma of the nerve-fibre connected with the cell. The nerve-cells in the ganglia of the spinal nerves (figs. 779, 780) are spherical in shape, and each gives off a single fibre which runs towards the centre of the ganglion, and divides in a T-shaped manner; one limb of the cross-bar enters the medulla spinalis, the other passes outwards to the periphery. Some of these fibres are medullated, others are non-medullated. In the sympathetic ganglia (Fig. 781) the nerve-cells are multipolar, and each has one axis-cylinder process and several dendrons; the axon emerges from the ganglion as a non-medullated nerve-fibre; some dendrons form networks (glomeruli) within the cell-capsules; others pierce the cell-capsules. The spinal and sympathetic ganglia differ somewhat in the size and disposition of the nerve-cells and in the number of nerve-fibres entering and leaving them. In the spinal ganglia (fig. 779) the nerve-cells are much larger and for the most part collected in

FIG. 781.—A section through a human sympathetic ganglion. Stained with hæmatoxylin and eosin. × 60.



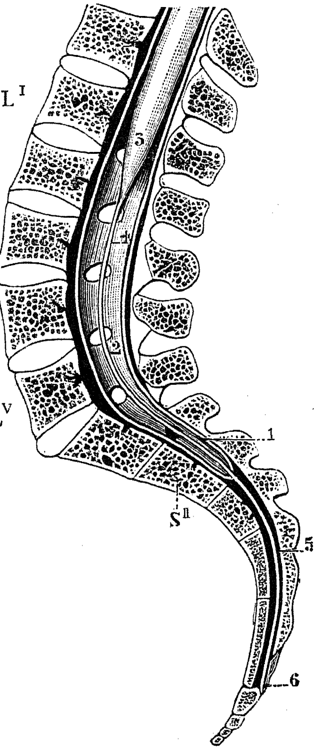
groups near the periphery, while the fibres, which are mostly medullated, traverse the central portion of the ganglion; in the sympathetic ganglia (fig. 781) the cells are smaller and distributed in irregular groups throughout the whole ganglion; the fibres also are irregularly scattered; some of those entering are medullated, while many leaving the ganglion are non-medullated.

Neuron theory.—The nerve-cell and its processes collectively constitute what is termed a *neuron*, and Waldeyer formulated the theory that the nervous system is built up of numerous neurons, 'anatomically and genetically independent of one another.' According to this *neuron theory* the processes of one neuron only come into contact, and are never in direct continuity, with those of other neurons; impulses being transmitted from one nerve-cell to another through the points of contact. This theory is based on the following facts, viz.: (1) each neuron is derived from a single embryonic nerve-cell or neuroblast; (2) when nervous tissues are stained by the Golgi method no continuity is seen even between neighbouring neurons; and (3) when degenerative changes occur in nervous tissue, either as the result of disease or experiment, they never spread from one neuron to another, but are limited to the individual neurons, or groups of neurons, primarily affected. It must, however, be added that the validity of the neuron theory has been called in question by certain eminent histologists who maintain that, by the employment of more delicate histological methods, minute fibrils can be followed from one nerve-cell into another.

The Medulla Spinalis or Spinal Cord

The **medulla spinalis** or **spinal cord** is the elongated, nearly cylindrical, part of the central nervous system which occupies the upper two-thirds of the vertebral canal. Its average length in the male is 45 cm.; its weight is about 30 gms. It extends from the level of the upper border of the atlas vertebra to that of the lower border of the first, or upper border of the second, lumbar vertebra. Above, it is continuous with the brain; below, it ends in the *conus medullaris*, from the apex of which a delicate non-nervous filament, the *filum terminale*, descends as far as the first segment of the coccyx (fig. 782).

Fig. 782.—A sagittal section through the vertebral canal showing the lower end of the medulla spinalis and the filum terminale. (Testut.)

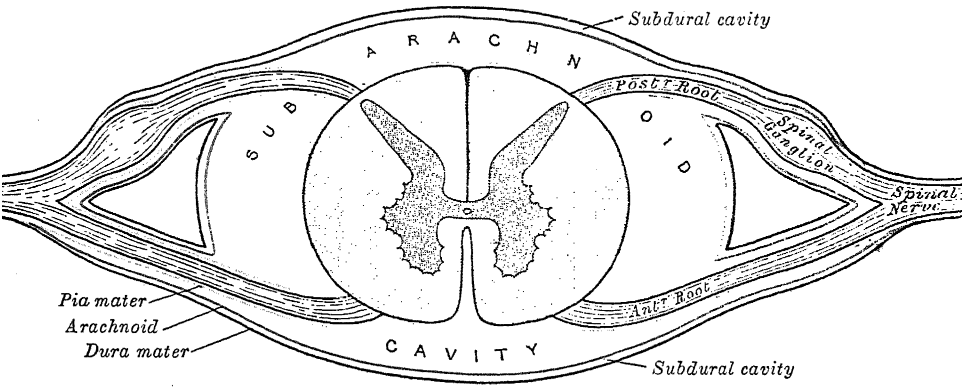


LI, LV. First and fifth lumbar vertebræ. SII. Second sacral vertebra. 1. Dura mater. 2. Lower part of tube of dura mater. 3. Lower end of medulla spinalis. 4. Intra-dural, and 5, extra-dural portions of filum terminale. 6. Attachment of filum terminale to first segment of coccyx.

The position of the medulla spinalis varies with the movements of the vertebral column, its lower extremity being raised slightly when the column is flexed. It also varies at different periods of life: in early fœtal life the medulla spinalis is as long as the vertebral canal, but after the embryo has attained a length of 30 mm. the vertebral column begins to grow farther caudalwards than the medulla spinalis, and the latter gradually assumes a higher position within the vertebral canal. The chief part of this upward migration occurs during the first half of fœtal life, so that by the twenty-fifth week of fœtal life the lower end of the medulla spinalis has ascended from the level of the second coccygeal vertebra to that of the third lumbar vertebra, *i.e.* a distance of nine segments, and there remain but two segments before the adult position is reached (Streeter). In the early embryo the nerve-roots pass transversely outwards to their respective intervertebral foramina, but owing to the relative inequality in the rates of growth of the medulla spinalis and vertebral column, the nerve-roots become more and more oblique in direction, so that in the adult the lumbar and sacral nerves descend almost vertically to reach their foramina. From the appearance these nerves present at their attachment to the medulla spinalis and from their great length they are collectively termed the *cauda equina* (fig. 784).

The medulla spinalis is ensheathed by three protective membranes separated from each other by spaces. The membranes are named from without inwards the dura mater, the arachnoid, and the pia mater (fig. 783). The *dura mater*, a strong, fibrous membrane, forms a wide, tubular sheath which extends below the termination of the medulla spinalis and ends in a pointed cul-de-sac at the level of the lower border of the second sacral vertebra. The dura mater is separated from the wall of the vertebral canal by the *epidural cavity*, which contains a quantity of areolar tissue, fat, and a plexus of veins ; between the dura mater and the subjacent arachnoid is the *subdural cavity*, a capillary interval containing a small quantity of fluid, probably of the nature of lymph. The *arachnoid* is a thin, transparent sheath which ends at the lower border of the second sacral vertebra ; it is separated from the pia mater by the *subarachnoid cavity*, which contains cerebrospinal fluid. The *pia mater* closely invests the medulla spinalis and sends delicate septa into its substance ; from either side of the pia mater a fibrous band, named the *ligamentum denticulatum*, projects into the subarachnoid space, and is attached by a series of pointed processes to the inner surface of the dura mater.

FIG. 783.—A transverse section through the medulla spinalis and its membranes. Diagrammatic.



Thirty-one pairs of spinal nerves spring from the medulla spinalis, each nerve having an anterior and a posterior root, the latter being distinguished by the presence of an oval swelling, the *spinal ganglion*, which contains numerous nerve-cells. Each root consists of several bundles of nerve-fibres, and at its attachment extends for some distance along the side of the medulla spinalis. The pairs of spinal nerves are grouped as follows: cervical 8, thoracic 12, lumbar 5, sacral 5, coccygeal 1, and, for convenience of description, the medulla spinalis is divided into cervical, thoracic, lumbar, and sacral regions, corresponding with the attachments of the different groups of nerves.

Although no trace of transverse segmentation is visible on the surface of the medulla spinalis, it is convenient to regard it as being built up of a series of superimposed *spinal segments* or *neuromeres*, to each of which is attached a pair of spinal nerves. The lower limit of each spinal segment may be represented by an imaginary transverse plane at the level of the highest roots of each pair of spinal nerves.

The *filum terminale* (figs. 782, 784) is a delicate filament, about 20 cm. long, continued downwards from the apex of the conus medullaris. Its upper part, or *filum terminale internum*, about 15 cm. long, is contained within the tubular sheath of dura mater and reaches as far as the lower border of the second sacral vertebra. It is surrounded by the nerves forming the cauda equina, but can be readily distinguished from them by its bluish-white colour. Its lower part, or *filum terminale externum*, is closely invested by, and adherent to, the dura mater ; it descends from the apex of the tubular sheath of dura mater and is

attached to the back of the first segment of the coccyx. The filum terminale consists mainly of fibrous tissue, continuous above with that of the pia mater, but adhering to its outer surface are a few strands of nerve-fibres which probably represent rudimentary second and third coccygeal nerves; further, the central canal of the medulla spinalis is continued downwards into it for 5 or 6 cm.

Enlargements.—The medulla spinalis is not quite cylindrical, being slightly flattened from before backwards; it also presents two swellings or enlargements, an upper or cervical, and a lower or lumbar (fig. 785).

Fig. 784.—The cauda equina and filum terminale seen from behind. The dura mater has been opened and spread out, and the arachnoid has been removed.

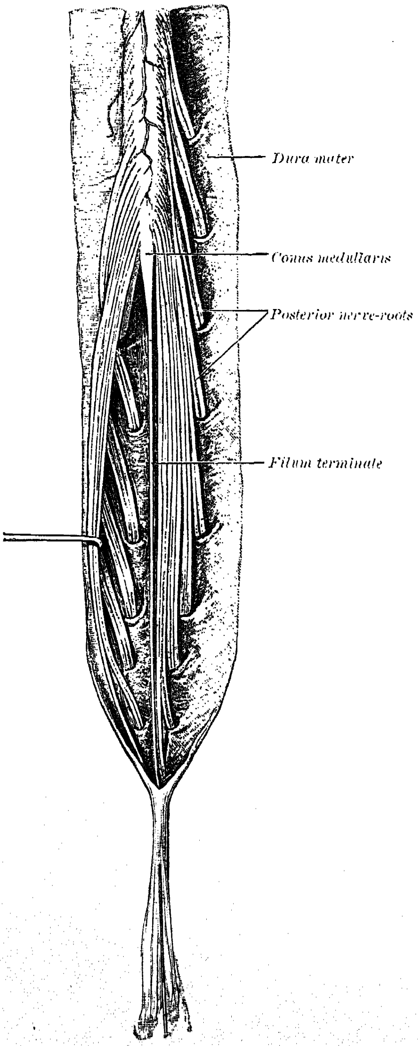
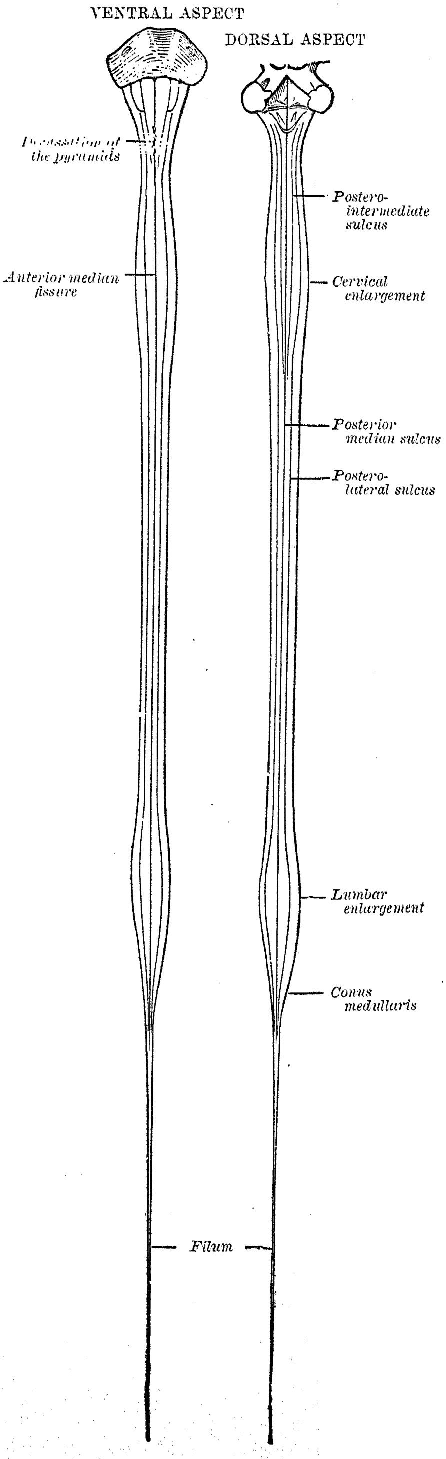


Fig. 785.—Diagrams of the medulla spinalis.



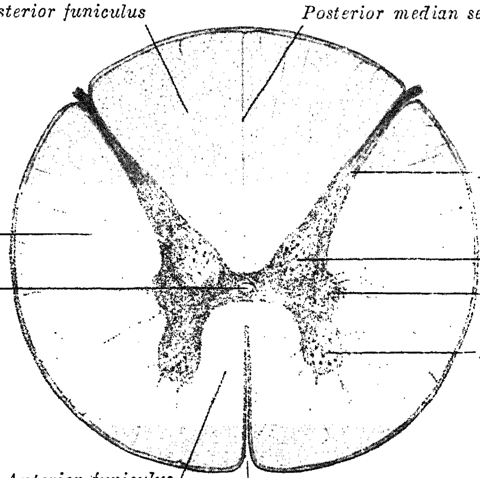
The *cervical enlargement* is the more pronounced, and corresponds with the attachments of the large nerves of the upper limbs. It extends from the third cervical to the second thoracic vertebra, its maximum circumference (about 38 mm.) being at the level of the roots of the sixth pair of cervical nerves.

To the *lumbar enlargement* are attached the nerves of the lower limbs. It begins at the level of the ninth thoracic vertebra, and reaches its maximum circumference, of about 33 mm., opposite the last thoracic vertebra, below which it tapers rapidly into the conus medullaris.

Fissures and sulci (fig. 786).—An anterior median fissure and a posterior median sulcus incompletely divide the medulla spinalis into two symmetrical parts, which are joined across the middle line by a commissural band of nervous matter.

The *anterior median fissure* has an average depth of about 3 mm., but is deepest in the lower part of the medulla spinalis. It contains a double fold of

FIG. 786.—A transverse section through the mid-thoracic region of the medulla spinalis. × 8.



pia mater, and its floor is formed by a transverse band of white substance, the *anterior white commissure*, which is perforated by blood-vessels on their way to or from the central part of the medulla spinalis.

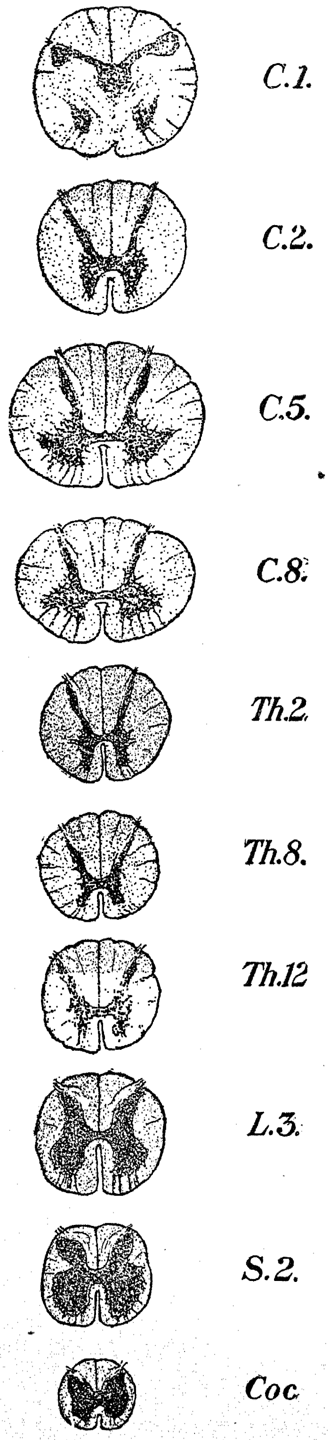
The *posterior median sulcus* is very shallow ; from it a septum of neuroglia reaches rather more than half-way into the substance of the medulla spinalis ; this septum varies in depth from 4 to 6 mm., but diminishes considerably in the lower part of the medulla spinalis.

On either side of the posterior median sulcus, and at a short distance from it, the posterior nerve-roots are attached along a vertical furrow named the *posterolateral sulcus*. The portion of the medulla spinalis which lies between this and the posterior median septum is named the *posterior funiculus*. In the cervical and upper thoracic regions the surface of this funiculus presents a longitudinal furrow, the *postero-intermediate sulcus* : this marks the position of a septum which extends into the posterior funiculus and subdivides it into two fasciculi—a medial, named the *fasciculus gracilis* (tract of Goll) ; and a lateral, the *fasciculus cuneatus* (tract of Burdach) (fig. 792).

The portion of the medulla spinalis between the posterolateral sulcus and the anterior median fissure is termed the *anterolateral region*. The anterior nerve-roots, unlike the posterior, are not attached in linear series, and their positions of exit are not marked by a sulcus ; they arise by separate bundles which spring from the anterior column of grey substance and, passing forward through the white substance, emerge over an area of some width. The line of emergence of the most lateral of these bundles is generally taken as a dividing

line which separates the anterolateral region into two parts, viz. an *anterior funiculus*, between the anterior median fissure and the most lateral of the anterior nerve-roots; and a *lateral funiculus*, between the exit of these roots and the posterolateral sulcus. In the upper part of the cervical region a series of nerve-roots passes outwards through the lateral funiculus; these unite to form the spinal portion of the accessory nerve, which ascends and enters the cranial cavity through the foramen magnum (fig. 801), and conveys to the accessory nerve the fibres which supply the Sternocleidomastoideus and Trapezius.

FIG. 787.—Transverse sections through the medulla spinalis at different levels.



THE INTERNAL STRUCTURE OF THE MEDULLA SPINALIS

The medulla spinalis is composed of grey and white nervous substance, in both of which there is a supporting framework of neuroglia.

The **grey substance** (substantia grisea) is enclosed within the white (fig. 786), and has the form of a fluted column which runs through the whole length of the medulla spinalis. This column consists of two symmetrical portions, one in either half of the medulla spinalis: these are joined to one another by a transverse commissure of grey substance which is traversed by the *central canal*, just visible to the naked eye. In a transverse section each half of the grey substance is shaped like a comma or crescent with its concavity directed lateralwards; and these, together with the intervening grey commissure, present the appearance of the letter **H**. A coronal plane through the central canal serves to divide each crescent into an anterior and a posterior column.

The **anterior column** (anterior cornu) is directed forwards; it is broad, and round or quadrangular in shape. Its posterior part is termed the *base*, and its anterior part the *head*, but these are not separated from each other by any well-defined constriction. Between the head of the column and the surface of the medulla spinalis is a layer of white substance which is traversed by the bundles of the anterior nerve-roots. In the thoracic region, the posterior part of the anterior column projects lateralwards, and is named the **lateral column** (lateral cornu).

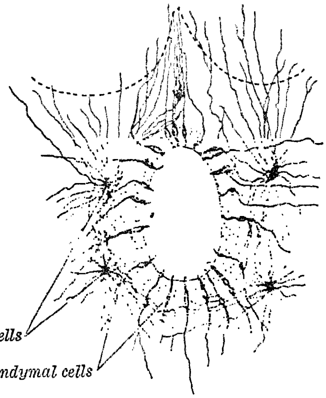
The **posterior column** (posterior cornu) is long and slender, and is directed backwards and lateralwards; it reaches almost as far as the posterolateral sulcus, from which it is separated by a thin layer of white substance, the *tract of Lissauer*. It consists of a *base*, directly continuous with the base of the anterior column, and a *neck* or slightly constricted portion, which is succeeded by an oval or fusiform area, termed the *head*, of which the *apex* approaches the posterolateral sulcus. The apex is capped by a mass of translucent, gelatinous neuroglia, termed the *substantia gelatinosa of Rolando*, which contains both neuroglia-cells and small

nerve-cells and is V-shaped or crescentic on transverse section. Between the anterior and posterior columns the grey substance extends as a series of processes into the lateral funiculus, and forms a network called the *formatio reticularis*.

The quantity of grey substance and the form it presents on transverse section vary at different levels. In the thoracic region the grey substance is small in amount, not only absolutely but relatively to the surrounding white substance. In the cervical and lumbar enlargements it is greatly increased; so that in the latter, and especially in the conus medullaris, its proportion to the white substance is greater than elsewhere (fig. 787). In the cervical region the posterior column of grey substance is comparatively narrow, while the anterior column is broad and expanded; in the thoracic region, both columns are narrow, and the lateral column is evident; in the lumbar enlargement the anterior and posterior columns are both expanded; while in the conus medullaris the grey substance assumes the form of two oval masses, one in either half of the cord, connected together by a broad grey commissure.

The **central canal** traverses the entire length of the medulla spinalis. It is continued upwards through the lower part of the medulla oblongata and opens into the fourth ventricle of the brain; below, it reaches for a short distance (5-6 cm.) into the filum terminale. In the lower part of the conus medullaris it exhibits a fusiform dilatation, the *terminal ventricle*: this has a vertical measurement of from 8 to 10 mm., is triangular on cross section with its base directed forwards, and tends to undergo obliteration after the age of forty years.

Fig. 788.—A transverse section through the central canal of the medulla spinalis, showing the ependymal and neuroglial cells. (Lenhossék.)



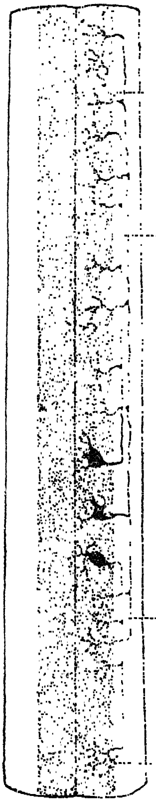
Throughout the cervical and thoracic regions the central canal is situated in the anterior one-third of the medulla spinalis: in the lumbar enlargement it is near the middle, and in the conus medullaris it approaches the posterior surface. It is filled with cerebrospinal fluid, and lined by ciliated, columnar epithelium, which is encircled by a band of gelatinous substance, the *substantia gelatinosa centralis*. This gelatinous substance consists mainly of neuroglia, but contains a few nerve-cells and nerve-fibres; it is traversed by processes from the deep ends of the cells which line the central canal (fig. 788).

The grey substance in front of the canal is named the anterior grey commissure; that behind it, the posterior grey commissure. The *anterior grey commissure* is thin, and in contact with the anterior white commissure: it contains a pair of longitudinal veins, one on either side of the middle line. The *posterior grey commissure* reaches from the central canal to the posterior median septum; it is thinnest in the thoracic region, and thickest in the conus medullaris.

The **structure of the grey substance**.—The grey substance of the medulla spinalis consists of neuroglia, nerve-cells, and nerve-fibres. Throughout the greater part of it the neuroglia is arranged in the form of a sponge-like network, but around the central canal and on the apices of the posterior columns it is condensed to form the gelatinous substance already referred to. The nerve-cells are multipolar, and vary greatly in size and shape, but they may be classified in three main types: (1) Motor-cells of large size, which are situated in the anterior column, and are especially numerous in the cervical and lumbar enlargements; the axons of most of these cells pass out to form the anterior nerve-roots, but before leaving the white substance they frequently give off collaterals, which re-enter and ramify in the grey

substance.* (2) Cells of small or medium size, the axons from which pass into the white matter, where some pursue an ascending, and others a descending course, but most of them divide in a T-shaped manner into descending and ascending processes; they give off collaterals which enter and ramify in the grey substance, and the axons end in a similar manner. Some of these axons are short and pass only between adjoining spinal segments; others are longer and connect more distant segments. These cells and their processes constitute a series of *association or intersegmental neurons* (fig. 789), which link together the different parts of the medulla spinalis. The axons of most of these cells are confined to that side of the medulla spinalis in which the nerve-cells are situated, but some cross to the opposite side through the anterior commissure, and are termed *crossed commissural fibres.* Some of the latter end directly in the grey substance, while others enter the white substance, and ascend or descend in it for varying distances, before finally terminating in the grey substance. Most of the nerve-cells are arranged in longitudinal columns, and appear as groups on transverse section (figs. 790, 791).

Fig. 789.—A diagram showing in longitudinal section the intersegmental neurons of the medulla spinalis. The grey and white parts correspond respectively to the grey and white substance of the medulla spinalis. (Poirier.)



Nerve-cells in the anterior column.—The nerve-cells in the anterior column are arranged in columns of varying length. The longest occupies the medial part of the anterior column and is named the *anteromedial* column: it is absent only in the fifth lumbar, the first sacral and the upper part of the second sacral segments. Behind it, is a *posteromedial* column of small cells, which extends from the second thoracic to the first lumbar segment and is also present in the lower two cervical segments.

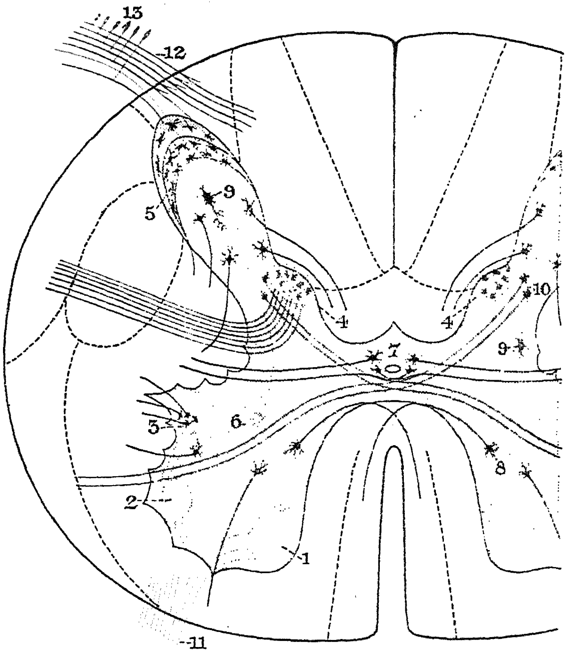
In the cervical and lumbar enlargements, where the anterior column is expanded in a lateral direction, the following additional columns of nerve-cells are present, viz.—(*a*) *anterolateral,* in the fourth, fifth, and sixth cervical, second thoracic, lower four lumbar and upper two sacral segments; (*b*) *posterolateral,* in the lower five cervical, lower four lumbar, and upper three sacral segments; (*c*) *post-posterolateral,* in the last cervical, first thoracic, and upper three sacral segments; and (*d*) *central,* in the lower four lumbar and upper two sacral segments. Throughout the base of the anterior column are solitary cells, the axons of some of which form crossed commissural fibres, while others constitute the motor fibres of the posterior nerve-root.*

Nerve-cells in the lateral column.—These form a column which is best marked in the thoracic region; it extends from the eighth cervical segment to the lower part of the second or upper part of the third lumbar segment, but can be traced throughout the length of the medulla spinalis in the form of groups of small cells situated in the anterior part of the formatio reticularis. The cells of this column are fusiform or star-shaped, and of a medium size: the axons of many of them pass into the anterior nerve-roots, and are conveyed to the sympathetic ganglia through the white rami communicantes; while the axons of others pass into the anterior and lateral funiculi, where they become longitudinal.

* Lenhossék and Cajal found that in the embryo of the chick the axons of a few of these nerve-cells passed backwards through the posterior column, and emerged as the *motor fibres* of the *posterior nervé-roots.* These fibres are said to control the peristaltic movements of the intestine. Their presence in man has not yet been determined.

Nerve-cells in the posterior column.—1. The *dorsal nucleus* (*column of Clarke*) occupies the medial part of the base of the posterior column, and appears on transverse section as a well-defined oval area (figs. 786, 791). It begins below at the level of the second or third lumbar nerve, and reaches its maximum size opposite the twelfth thoracic nerve. It diminishes in size above the level of the ninth thoracic nerve, and ends opposite the last cervical or first thoracic nerve. It is represented, however, in the other regions by scattered cells, which are aggregated to form a *cervical nucleus* opposite the third cervical nerve, and a *sacral nucleus* in the middle and lower part of the sacral region.

FIG. 790.—A scheme showing the mode of distribution of the nerve-cells in the grey substance. (Testut.)



1, 2. Medial and lateral groups of nerve-cells in anterior column. 3. Nerve-cells in lateral column. 4, 4. Dorsal nucleus. 5. Group of nerve-cells in substantia gelatinosa of Rolando. 6. Nerve-cell of anterior column, the axon of which is passing into the posterior nerve-root. 7. Cells of substantia gelatinosa centralis. 8. Solitary cell. 9. Cells of Golgi. 10. Cells of origin of the superficial anterolateral fasciculus. 11. Anterior root. 12. Posterior root. 13. Spinal ganglion.

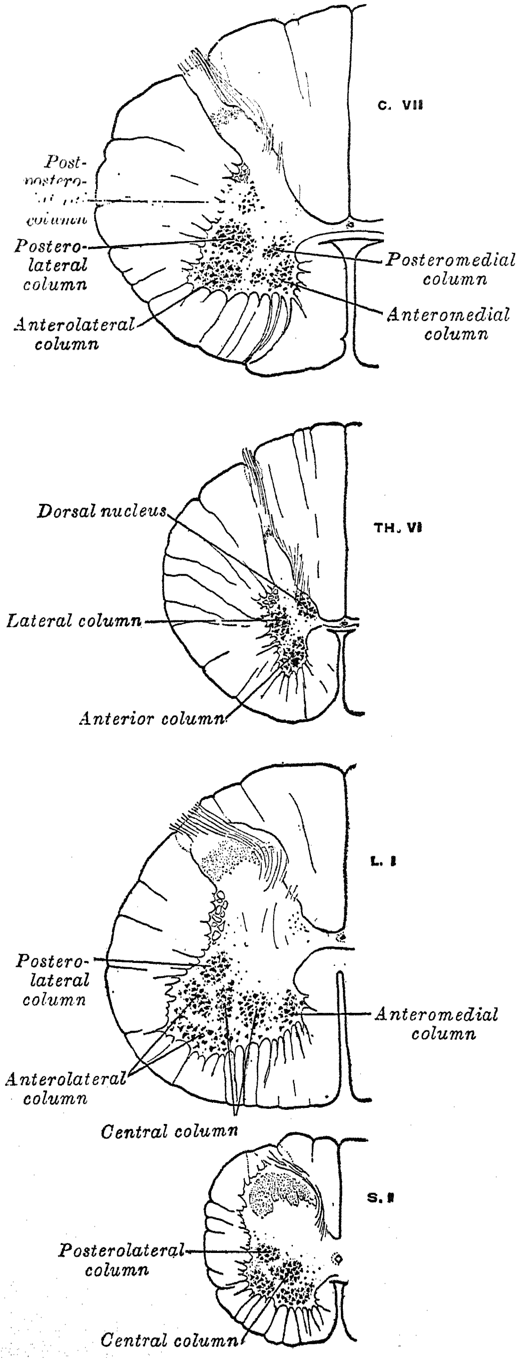
Its cells are of medium size, and oval or pyriform in shape; many of their axons pass into the peripheral part of the lateral funiculus of the same side, and there ascend, under the name of the *direct cerebellar tract*; others cross to the opposite side and ascend as the *superficial anterolateral fasciculus*.

2. *Nerve-cells in the substantia gelatinosa of Rolando.*—These are arranged in three zones: a posterior or marginal, of large triangular or fusiform cells; an intermediate, of small fusiform cells; and an anterior, of star-shaped cells. The axons of these cells pass into the lateral and posterior funiculi, and there pursue a vertical course. Some of the cells in the anterior zone belong to Golgi's type II, their short axons being confined to the grey substance.

3. *Solitary cells* of varying form and size are scattered throughout the posterior column. Some of these are grouped to form an ill-defined *posterior basal column*, lateral to the dorsal nucleus. The axons of the cells of this column pass partly to the posterior and lateral funiculi of the same side, and partly through the anterior white commissure to the lateral funiculus of the opposite side. Before leaving the grey substance, a considerable number run longitudinally for a varying distance in the head of the posterior column, forming what is termed the *longitudinal fasciculus* of the posterior column.

A few star-shaped or fusiform nerve-cells of varying size are found in the substantia gelatinosa centralis. Their axons pass into the lateral funiculus of the same, or the opposite, side.

Fig. 791.—Transverse sections through the medulla spinalis at different levels, showing the arrangement of the principal cell-columns.

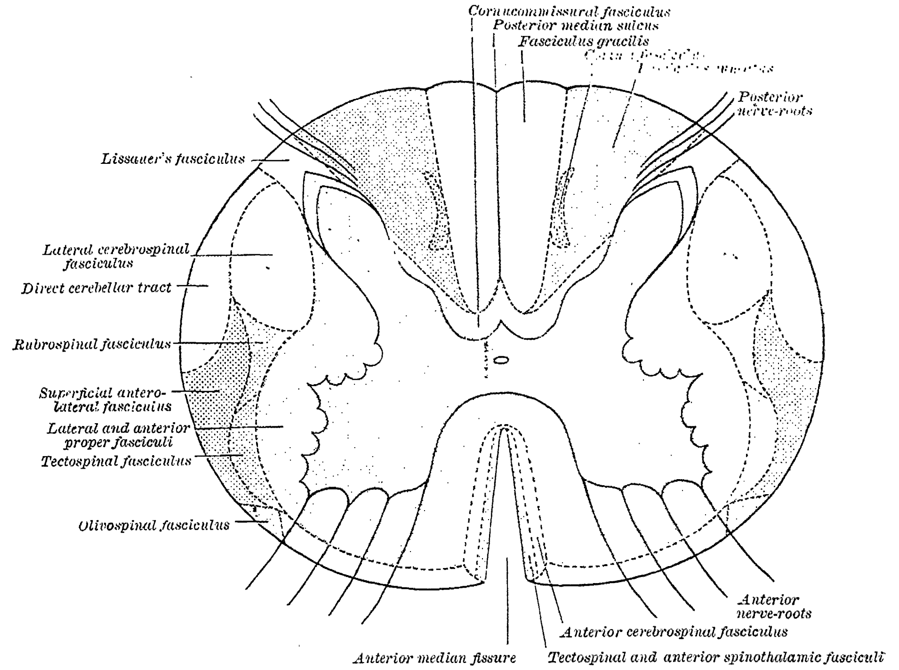


The nerve-fibres in the grey substance form a dense interlacement among the nerve-cells. This interlacement is formed partly of axons which pass from the cells in the grey substance to enter the white funiculi or the anterior nerve-roots; partly of the axons of Golgi's cells which ramify only in the grey substance; and partly of collaterals from the nerve-fibres in the white funiculi, which, as already stated, enter the grey substance and ramify within it.

The **white substance** (substantia alba) of the medulla spinalis surrounds the grey substance, and consists chiefly of medullated nerve-fibres. The nerve-fibres are arranged in three funiculi: anterior, lateral, and posterior. The anterior funiculus lies between the anterior median fissure and the most lateral of the anterior nerve-roots; the lateral funiculus between these nerve-roots and the posterolateral sulcus; and the posterior funiculus between the posterolateral sulcus and the posterior median septum (fig. 792). The nerve-fibres vary in thickness; the thinnest are found in the fasciculus gracilis, the fasciculus of Lissauer, and the central part of the lateral funiculus; the thickest are situated in the anterior funiculus, and in the peripheral part of the lateral funiculus. Some of the nerve-fibres run more or less transversely, as for example those which cross the middle line in the anterior white commissure, but the majority pursue a longitudinal course and are divisible into (1) those connecting the medulla spinalis with the brain and conveying impulses to or from the latter, and (2) those which are confined to the medulla spinalis, and link together its different segments (i.e. intersegmental or association fibres).

Nerve-fasciculi.—The longitudinal fibres are grouped into more or less definite bundles or fasciculi. These are not recognisable from each other in the natural state, and their existence has been determined by the following methods. (1) A. Waller discovered that if a bundle of nerve-fibres be cut, the portions of the fibres which are separated from their cells rapidly degenerate and become atrophied, while their cells and the parts of the fibres connected with them undergo little alteration.* This is known as *Wallerian degeneration.* Similarly, if a group of nerve-cells be destroyed, the fibres arising from them undergo degeneration. Thus, if the motor cells of the cerebral cortex be destroyed, or if the fibres arising from these cells be severed, a *descending degeneration* from the seat of injury takes place in the fibres. In the same manner, if a spinal ganglion be destroyed, or the fibres which pass from it

FIG. 792.—A diagram of the principal fasciculi of the white substance of the medulla spinalis.



into the medulla spinalis be cut, an *ascending degeneration* occurs in these fibres above the lesion. (2) In the early stages of the development of the nervous system, the nerve-fibres are naked axis-cylinders; groups of nerve-fibres acquire their medullary sheaths at different periods; hence the fibres can be grouped according to the dates at which they receive these sheaths. The first fibres to acquire medullary sheaths are those of the nerve-roots and of the fasciculi proprii; the last, those of the cerebrospinal fasciculi. (3) Golgi's method of staining nervous tissues allows the course and mode of termination of the axis-cylinder processes to be followed.

Fasciculi in the anterior funiculus.—(*a*) The *anterior cerebrospinal fasciculus* (direct pyramidal tract) is usually small, but varies in size inversely with the lateral cerebrospinal fasciculus. It is present only in the upper part of the medulla spinalis; gradually diminishing in size as it descends, it ends about the middle of the thoracic region. It consists of fibres which arise from cells in the motor area of the cerebral hemisphere of the same side, and which,

* Somewhat later a change, termed *chromatolysis,* takes place in the nerve-cells, and consists of the breaking down and ultimate disappearance of the Nissl bodies. The cell-body swells, the nucleus is displaced towards the periphery of the cell, and the part of the axon still attached to the altered cell diminishes in size and atrophies. Under favourable conditions the cell may resume its normal appearance, and its axon may grow again.

as they run downwards in the medulla spinalis, cross in succession through the anterior white commissure to the opposite side, where they end by arborising around the motor cells in the anterior column.

(*b*) The *vestibulospinal fasciculus*, derived from the cells of Deiters' nucleus, one of the nuclei in which the vestibular division of the acoustic nerve ends, descends in the anterior funiculus.

(*c*) The *anterior spinothalamic* fasciculus arises from cells in the posterior grey column of the opposite side of the medulla spinalis, crosses in the anterior white commissure, and ascends in the anterior funiculus to the thalamus.

The remaining fibres of the anterior funiculus constitute what is termed the *fasciculus proprius anterior* (anterior basis bundle). It consists mainly of: (1) longitudinal intersegmental fibres which arise from cells in the grey substance, more especially from those of the medial group of the anterior column, and, after a longer or shorter course, re-enter the grey substance. Some of the fibres of this fasciculus pass upwards into the medial (posterior) longitudinal fasciculus (p. 827); (2) fibres arising from cells of the cerebellum and extending down the medulla spinalis to end around the cells of the anterior column.

Fasciculi in the lateral funiculus.—1. **Descending fasciculi.**—(*a*) The *lateral cerebrospinal fasciculus* (crossed pyramidal tract) extends throughout the length of the medulla spinalis, and on transverse section appears as an oval area in front of the posterior grey column and medial to the direct cerebellar tract. In the lumbar and sacral regions, where the direct cerebellar fasciculus is absent, the lateral cerebrospinal fasciculus reaches the surface of the medulla spinalis. Its fibres arise from cells in the motor area of the cerebral hemisphere of the opposite side. They pass downwards in company with those of the anterior cerebrospinal fasciculus through the same side of the brain as that from which they originate, but cross to the opposite side in the medulla oblongata and descend in the lateral funiculus of the medulla spinalis; they end by arborising around the motor cells in the anterior column.*

The anterior and lateral cerebrospinal fasciculi constitute the motor fasciculi of the medulla spinalis and have their origins in the motor cells of the cerebral cortex. They descend through the internal capsule of the cerebrum, traverse the cerebral peduncles and pons, and enter the pyramid of the medulla oblongata. In the lower part of the latter about two-thirds of them cross the middle line and run downwards in the lateral funiculus as the lateral cerebrospinal fasciculus while the remaining fibres do not cross, but are continued into the same side of the medulla spinalis, where they form the anterior cerebrospinal fasciculus. Fibres of the latter, however, cross in succession through the anterior white commissure, and thus, generally speaking, all the motor fibres from one side of the brain reach the opposite side of the medulla spinalis. The proportion of fibres which cross in the medulla oblongata is not a constant one, and thus the anterior and lateral cerebrospinal fasciculi vary inversely in size. Sometimes the former is absent, and it is then presumed that complete decussation of the motor fibres has occurred in the medulla oblongata. Medullation of the fibres of these two fasciculi is not completed until the second year. There is experimental and clinical evidence to show that the lateral cerebrospinal fasciculus contains a few fibres which are derived from the cerebral hemisphere of the same side (*uncrossed lateral cerebrospinal fibres*).

(*b*) The *rubrospinal fasciculus* (Monakow) is anterior to the lateral cerebrospinal fasciculus, and on transverse section appears as a somewhat triangular area. Its fibres descend from the mid-brain, where they have their origins in the cells of the red nucleus of the tegmentum of the opposite side; they end by forming synapses with the cells in the anterior column.

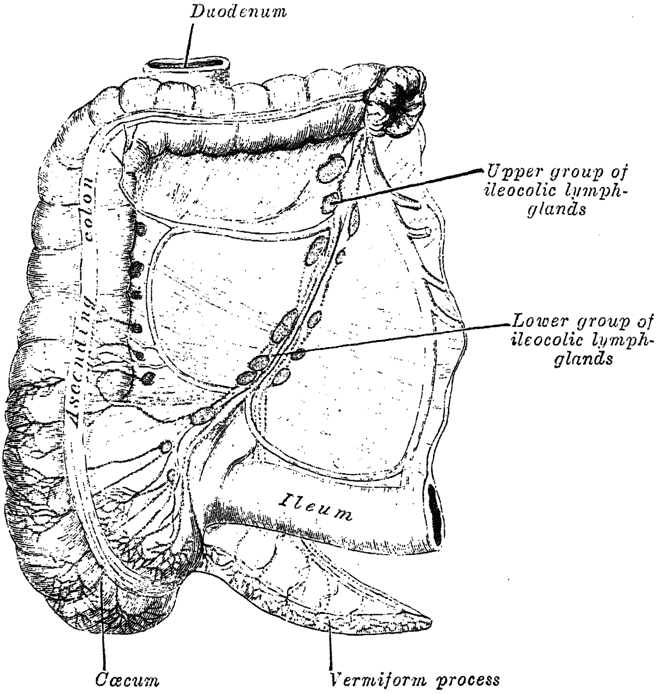
(*c*) The *tectospinal fasciculus* originates in the superior colliculus (upper quadrigeminal body) of the opposite side, and its fibres are partly intermingled with those of the rubrospinal fasciculus, and are partly contained in the anterior funiculus.

* Sharpey Schafer (*Proc. Physiological Soc.* 1899) says it is probable that the fibres of the anterior and lateral cerebrospinal fasciculi are not related in this direct manner with the cells of the anterior column, but terminate by arborising round the cells at the base of the posterior column, which in turn link them to the motor cells in the anterior column, usually of several segments of the cord. In consequence of these interposed neurons the fibres of the cerebrospinal fasciculi correspond, not to individual muscles, but to associated groups of muscles.

colon; their efferents pass to the superior mesenteric group of pre-aortic lymph-glands.

The **inferior mesenteric lymph-glands** (fig. 771) consist of: (*a*) small glands on the branches of the left colic and sigmoid arteries; (*b*) a group in the sigmoid mesocolon, around the superior hæmorrhoidal artery; and (*c*) a

FIG. 769.—The lymphatics of the cæcum and vermiform process. Anterior aspect. (Jamieson and Dobson.)



pararectal group in contact with the muscular coat of the rectum. The inferior mesenteric lymph-glands drain the descending and sigmoid parts of the colon and the upper part of the rectum; their efferents pass to the inferior mesenteric group of pre-aortic lymph-glands.

THE LYMPHATIC VESSELS OF THE ABDOMEN AND PELVIS

The lymphatic vessels of the abdomen and pelvis may be divided into 1. parietal and 2. visceral.

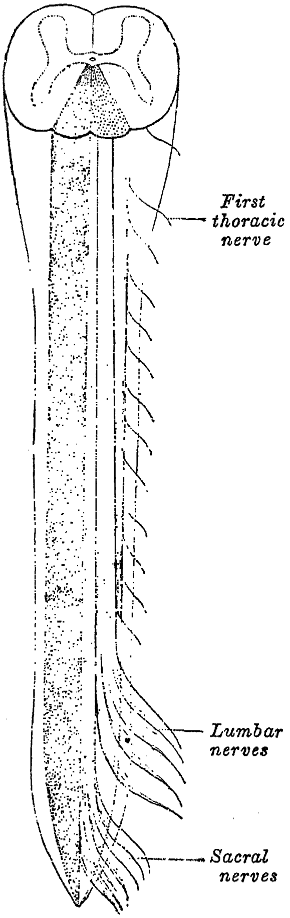
1. The **parietal lymphatic vessels** consist of two sets, superficial and deep.

The *superficial lymphatic vessels* follow the course of the superficial blood-vessels, and converge to the axillary and the superficial inguinal lymph-glands; those from the skin above the level of the umbilicus pass to the pectoral and subscapular groups of axillary lymph-glands; those derived from the skin of the front of the abdomen below the umbilicus follow the course of the superficial epigastric vessels, and those from the sides of the lumbar part of the abdominal wall pass along the crest of the ilium, with the superficial iliac circumflex vessels. The superficial lymphatic vessels of the glutæal region turn horizontally round the buttock, and join the superficial inguinal and subinguinal lymph-glands.

The *deep lymphatic vessels* run alongside the principal blood-vessels. Those of the parietes of the pelvis, which accompany the superior and inferior glutæal

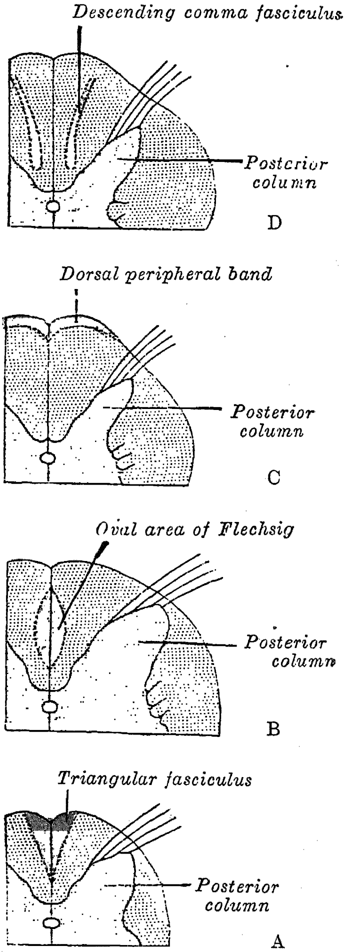
Occupying the anterior or deepest part of the posterior funiculus is a strand of fibres termed the *cornucommissural fasciculus*. It is somewhat crescentic on transverse section, and is placed between the posterior grey commissure and the posterior funiculus ; it is best marked in the lumbar region, but can be traced into the thoracic and cervical regions. Its fibres, derived from the cells of

Fig. 793.—A diagram showing the formation of the fasciculus gracilis. (Poirier.)



The medulla spinalis viewed from behind. To the left, the fasciculus gracilis is shaded. To the right, the drawing shows that the fasciculus gracilis is formed by the long ascending fibres of the posterior roots and that the sacral nerves lie next the median plane, the lumbar to their lateral side, and the thoracic still more laterally.

Fig. 794.—The descending fibres in the posterior funiculi, shown at different levels. (After Testut.)



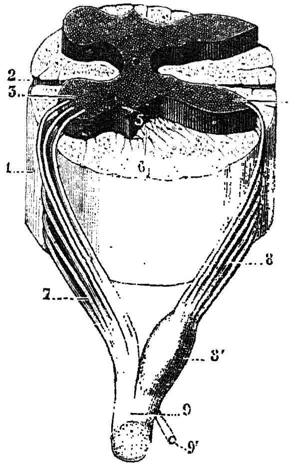
A. In the conus medullaris. B. In the lumbar region. C. In the lower thoracic region. D. In the upper thoracic region.

the posterior column, divide into ascending and descending branches which re-enter and ramify in the grey substance. This fasciculus has been found to preserve its integrity in certain cases of locomotor ataxia.

The posterior funiculus contains some descending fibres which occupy different parts at different levels (fig. 794). In the cervical and upper thoracic regions they appear as a *comma-shaped fasciculus* in the medial part of the fasciculus cuneatus, the blunt edge of the fasciculus being directed forwards ; in the lower thoracic region they form a *dorsal peripheral band* on the posterior surface of the funiculus ; in the lumbar region they are situated by the side of

the posterior median septum, and appear on section as a semi-elliptical bundle, which, together with the corresponding bundle of the opposite side, forms the *oval area of Flechsig*; while in the conus medullaris they assume the form of a *triangular strand* in the posteromedial part of the fasciculus gracilis. These descending fibres are mainly intersegmental in character and derived from cells in the posterior column, but some consist of the descending branches of the posterior nerve-roots. The comma-shaped fasciculus was supposed to belong to the second category, but against this view is the fact that it does not undergo descending degeneration when the posterior nerve-roots are destroyed.

Fig. 795.—A spinal nerve with its anterior and posterior roots. (Testut.)



1. A portion of the medulla spinalis viewed from the left side. 2. Anterior median fissure. 3. Anterior column. 4. Posterior column. 5. Lateral column. 6. Formatio reticularis. 7. Anterior root. 8. Posterior root, with 8′, its ganglion. 9. Spinal nerve; and 9′, its posterior division.

Roots of the spinal nerves.—Each spinal nerve has two roots, an anterior and a posterior, which are attached to the surface of the medulla spinalis opposite the corresponding columns of grey substance (fig. 795); their fibres acquire their medullary sheaths about the fifth month of fœtal life.

The *anterior nerve-root* consists of efferent fibres, which are the axons of the nerve-cells in the anterior and lateral grey columns. A short distance from their origins, these axons are invested by medullary sheaths and, passing forwards, emerge in two or three irregular rows over an area which measures about 3 mm. in width.

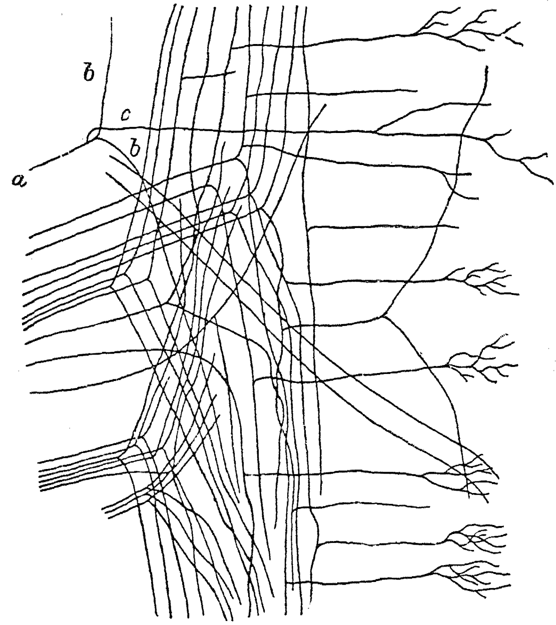
The *posterior nerve-root* comprises six or eight fasciculi, attached in linear series along the posterolateral sulcus. It consists of afferent fibres which arise from the nerve-cells in a spinal ganglion. Each ganglion-cell gives off a single fibre which divides in a T-shaped manner into two processes, medial and lateral. The medial processes of the ganglion-cells pass into the medulla spinalis as the posterior roots of the spinal nerves, while the lateral are directed towards the periphery.

The posterior nerve-root enters the medulla spinalis in two chief bundles, medial and lateral. The *medial* strand passes directly into the fasciculus cuneatus; it consists of coarse fibres, which acquire their medullary sheaths about the fifth month of intra-uterine life; the *lateral* strand is mainly composed of fine fibres, many of which are non-medullated; they enter the fasciculus of Lissauer.

After entering the medulla spinalis, all the fibres of the posterior nerve-roots divide into ascending and descending branches, and these in their turn give off collaterals which enter the grey substance (fig. 796). The descending branches are short, and soon enter the grey substance. The ascending branches are grouped into long, short, and intermediate fibres; the long fibres ascend in the fasciculus cuneatus and fasciculus gracilis as far as the medulla oblongata, where they end by arborising around the cells of the cuneate and gracile nuclei; the short fibres run upwards for a distance of only 5 or 6 mm., and enter the grey substance; while the intermediate fibres, after a somewhat longer course, have a similar destination. All fibres entering the grey substance end by arborising around its nerve-cells; in the thoracic region those of intermediate length are especially associated with the cells of the dorsal nucleus. The collaterals which spring from the ascending and descending branches of the fibres of the posterior nerve-roots end by arborising around the cells in the anterior and posterior grey columns; in the thoracic region many of these collaterals arborise around the cells of the dorsal nucleus and the cells of the lateral grey column.

The long ascending fibres of the posterior nerve-roots pursue an oblique course, being situated at first in the lateral part of the fasciculus cuneatus; higher up, they occupy the middle of this fasciculus, having been displaced by the accession of other entering fibres; while still higher, they ascend in the fasciculus gracilis. In the upper cervical region the localisation of these fibres is very precise: the sacral nerves lie in the medial part of the fasciculus gracilis and near its base, the lumbar nerves lateral to them, the thoracic nerves still more laterally; while the cervical nerves are confined to the fasciculus cuneatus (fig. 793).

FIG. 796.—The posterior nerve-roots dividing into ascending and descending branches. (Van Gehuchten.)



a. Nerve-fibre. *b, b.* Ascending and descending branches. *c.* Collateral arising from nerve-fibre.

The development of the medulla spinalis is described on pp. 85 to 88.

Applied Anatomy.—Several cases have been recorded* in which a local doubling of the medulla spinalis has taken place. The condition is probably due to some interference with the development of the neural tube in the embryo; in a few it was associated with spina bifida, while in one case † the two parts were separated by a dermoid tumour. Other *congenital abnormalities* of the medulla spinalis occur in connexion with spina bifida (p. 184), and *syringomyelia.* In this latter chronic condition an abnormal proliferation of the neuroglia takes place, generally near the central canal and usually in the cervical enlargement, and later this mass becomes absorbed, leaving an irregular cavity in its place. This gives rise to a number of interesting signs and symptoms, such as analgesia (or insensitiveness to pain), inability to distinguish between cold and heat, progressive atrophy in the muscles of the hands and arms, trophic changes in the bones and joints, and painless whitlows. Severe *injuries* to the medulla spinalis may occur in fractures or fracture-dislocations of the vertebral column anywhere above the second lumbar vertebra. If the medulla spinalis is completely crushed or torn across, total paralysis and anæsthesia of all parts of the body drawing their nerve supply from below the injured spot will follow, with loss of control over the actions of the bladder and rectum. The higher up such a lesion occurs, the worse the prognosis. Thus, in fracture of the atlas or epistropheus, the vital centres in the medulla oblongata are injured, and death occurs at once. If the origin of the phrenic nerve—mainly the fourth cervical—just escape in a case where the neck is broken, respiration will have to be carried on by the Diaphragm alone, and death is likely to ensue before long from pulmonary complications. When the back is broken in the lower thoracic region, life is not immediately threatened; but unless the patient is carefully nursed, death may follow at any time from the development of bed sores in the anæsthetic area, or from septic infection spreading up the ureters into the kidneys and secondary to the cystitis that is so prone to occur in patients who have no control over the bladder. *Inflammation* of the medulla spinalis, or *spinal myelitis,* sometimes follows influenza or one of the acute specific fevers. A transverse patch of such myelitis extending completely across the medulla spinalis produces more or less complete interruption of the passage of nervous impulses through it. Hence it will occasion more or less complete paralysis and anæsthesia of the parts of the body obtaining their nerve-supply from below it, and, in addition, a zone of cutaneous hyperæsthesia at its level, in consequence of the irritation of the sensory fibres entering the inflamed region of the medulla spinalis. The disease mainly attacking children, and known as *infantile spinal paralysis,* or *acute anterior*

* An analysis of these cases is given in the *Review of Neurology and Psychiatry,* Jan. 1916.

† Harriehausen, *D. Ztschrft. f. Nervenheilk.* Bd. 36, Hft. 3 und 4, S. 268.

poliomyelitis, is a bacterial infection of the pia mater that spreads into the medulla spinalis along the blood-vessels, and destroys groups of the motor neurons aggregated in the anterior column. Destruction of the cells causes rapid and sometimes permanent paralysis of the muscles innervated, and groups of muscles in one or more of the limbs are commonly picked out for attack. The affected limbs are thus partially paralysed, and their subsequent growth and nutrition both suffer. Further, the muscles that normally antagonise the affected groups of muscles, finding their actions unopposed, tend to assume a state of spastic contraction. In consequence, much dwarfing and deformity follow later, and may demand for their relief such operations as tenotomy, the transplantation of tendons, or even amputation.

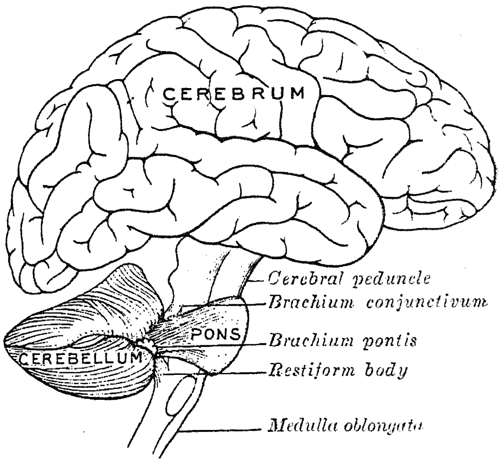
Inflammation of the ganglia on one or more of any of the posterior nerve-roots is the cause of *shingles* or herpes zoster, in which there is a painful eruption of groups of cutaneous vesicles corresponding to the distribution of the nerves derived from the affected ganglia. It is commonest along the course of the intercostal nerves; the eruption is often preceded and followed, as well as accompanied, by girdle pains, and in old people these may be prolonged and serious in character. Herpes is the analogue on the sensory side to anterior poliomyelitis on the motor side of the nervous system.

THE ENCEPHALON OR BRAIN

General Considerations and Divisions

The encephalon, or brain, is the upper, expanded part of the central nervous system, and is contained within the cranium. In the early embryo it consists of three hollow vesicles, termed the *rhombencephalon* or *hind-brain*, the *mesencephalon* or *mid-brain*, and the *prosencephalon* or *fore-brain*; and the parts derived from each of these can be recognised in the adult (fig. 797). The wall of the rhombencephalon is modified to form the medulla oblongata, pons, and cerebellum, while its cavity is expanded to form the fourth ventricle. The mesencephalon forms only a small part of the adult brain; its cavity becomes the cerebral aqueduct (aqueduct of Sylvius), and serves as a tubular communication between the third and fourth ventricles; its walls are thickened to form the corpora quadrigemina and the cerebral peduncles. The prosencephalon undergoes great modification; the anterior part (telencephalon) expands laterally as two hollow vesicles the cavities of which become the lateral ventricles, while the surrounding walls form the cerebral hemispheres and their commissures; the cavity of the posterior part (diencephalon) forms the greater part of the third ventricle, and from its walls are developed most of the structures which bound that cavity. Further details regarding these important changes are given on pages 90 to 100.

Fig. 797.—A scheme showing the connexions of the several parts of the brain. (After Schwalbe.)



THE RHOMBENCEPHALON OR HIND-BRAIN

The **rhombencephalon or hind-brain** occupies the posterior fossa of the cranial cavity and lies below a fold of dura mater, named the tentorium cerebelli. It consists of (*a*) the *myelencephalon*, comprising the medulla oblongata and the lower part of the fourth ventricle; (*b*) the *metencephalon*, consisting of the pons, cerebellum, and the intermediate part of the fourth ventricle; and (*c*) the *isthmus rhombencephali*, a constricted portion immediately adjoining the mesencephalon and including the brachia conjunctiva of the cerebellum, the anterior medullary velum, and the upper part of the fourth ventricle.

The Medulla Oblongata

The **medulla oblongata**, the lowest division of the brain, is extremely complex in structure, since it gives attachment to many of the cerebral nerves, and forms the connecting link between the medulla spinalis below and the cerebrum and cerebellum above.

It extends from the lower margin of the pons to a plane passing transversely below the pyramidal decussation and above the first pair of cervical nerves; this plane corresponds with the upper border of the atlas behind, and the middle of the dens of the epistropheus in front; at this level the medulla oblongata is continuous with the medulla spinalis. The anterior surface of the medulla oblongata is separated from the basilar part of the occipital bone and the upper part of the dens of the epistropheus by the membranes of the brain and the occipito-axial ligaments. Its posterior surface is received into the fossa between the hemispheres of the cerebellum, and the upper portion of it forms the lower part of the floor of the fourth ventricle. The vertebral arteries pass upwards and forwards in relation to its lateral surfaces; they then curve forwards to its anterior surface and unite at the lower border of the pons to form the basilar artery.

The medulla oblongata is pyramidal in shape (fig. 798), its broad extremity being directed upwards towards the pons, while its narrow lower end is continuous with the medulla spinalis. It measures about 3 cm. longitudinally, 2 cm. transversely at its widest part, and 1·25 cm. anteroposteriorly. The central canal of the medulla spinalis is prolonged into its lower half, and then opens into the cavity of the fourth ventricle; the medulla oblongata may therefore be divided into a lower *closed part* containing the central canal, and an upper *open part* corresponding with the lower portion of the fourth ventricle. Its anterior and posterior surfaces are marked by median fissures.

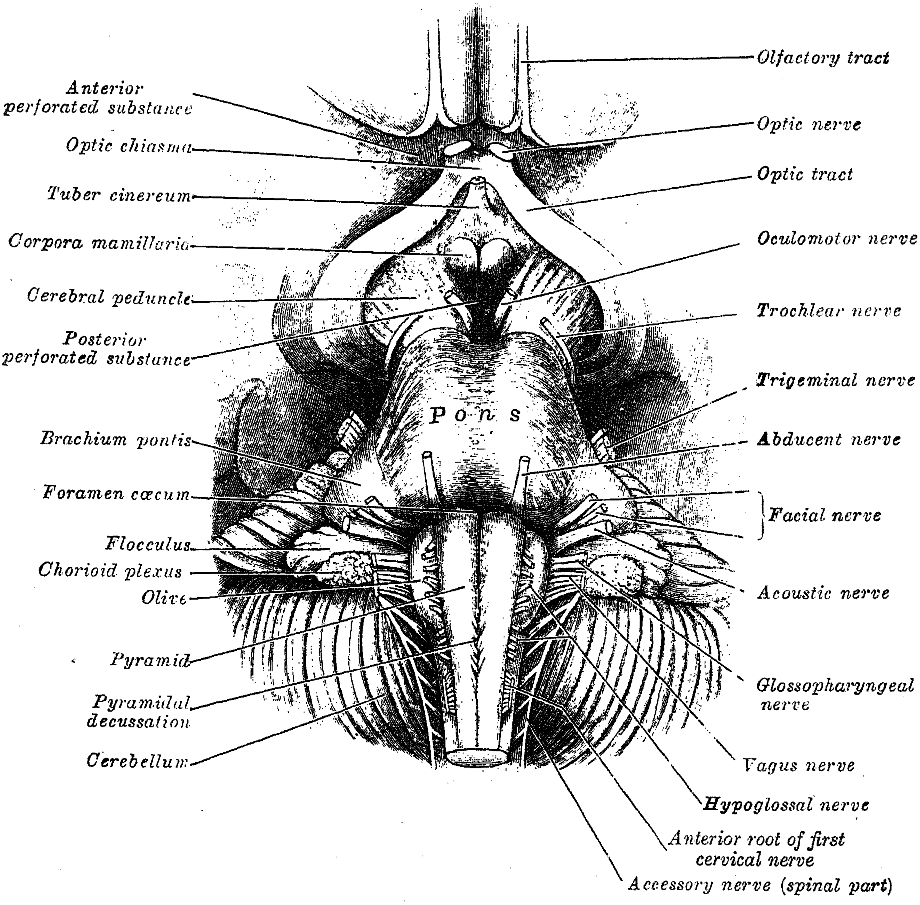
The **anterior median fissure** contains a fold of pia mater, and extends along the entire length of the medulla oblongata; below, it is continuous with the anterior median fissure of the medulla spinalis; above, it ends at the lower border of the pons in a small triangular expansion, termed the *foramen cæcum*. Its lower part is interrupted by bundles of fibres which cross obliquely from one side to the other, and constitute the *pyramidal decussation*. Some fibres, termed the *external arcuate fibres*, emerge from the fissure above this decussation and curve lateralwards and upwards over the surface of the medulla oblongata.

The **posterior median fissure** is a narrow groove which exists only in the closed part of the medulla oblongata; it is continuous below with the posterior median sulcus of the medulla spinalis, becomes gradually shallower from below upwards, and finally ends about the middle of the medulla oblongata, where the central canal expands into the cavity of the fourth ventricle.

These two fissures divide the closed part of the medulla oblongata into lateral halves which, on surface view, appear to be continuous with the halves of the medulla spinalis. In the open part the halves are separated by the anterior median fissure, and by a median *raphe* which extends from the bottom of the fissure to the median sulcus of the rhomboid fossa or

floor of the fourth ventricle. Further, certain of the cerebral nerves pass through the substance of the medulla oblongata, and are attached to its surface in series with the roots of the spinal nerves; thus, the fibres of the hypoglossal nerve correspond in position with the anterior roots of the spinal nerves, and emerge in linear series from a furrow termed the *antero-lateral sulcus*. Similarly, the accessory, vagus, and glossopharyngeal nerves correspond with the posterior roots of the spinal nerves, and are attached to the bottom of a sulcus named the *posterolateral sulcus*. Advantage is taken

FIG. 798.—The medulla oblongata, pons and mid-brain. Ventral aspect.



of this arrangement to subdivide each half of the medulla oblongata into anterior, middle, and posterior regions. Although these three regions appear to be directly continuous with the corresponding funiculi of the medulla spinalis, they do not necessarily contain the same nerve-fibres, since some of the fasciculi of the medulla spinalis end in the medulla oblongata, while others alter their course in passing through it.

The **anterior region** of the medulla oblongata (fig. 798) is named the *pyramid*, and lies between the anterior median fissure and the anterolateral sulcus. Its upper end is slightly constricted, and between it and the pons the fibres of the abducent nerve emerge; below, it tapers into the anterior funiculus of the medulla spinalis, with which, at first sight, it appears to be directly continuous.

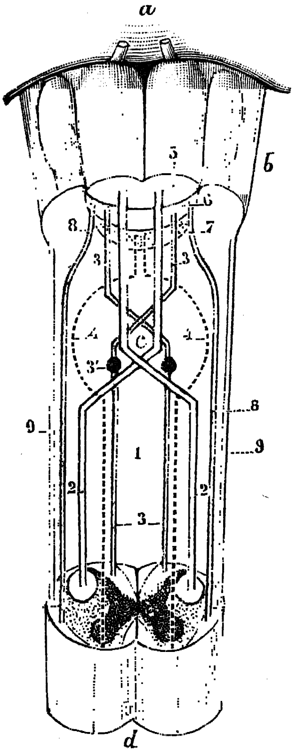
The two pyramids contain the motor fibres which pass from the brain to the medulla spinalis. When traced downwards, two-thirds or more of these

fibres leave the pyramids in successive bundles, and decussate in the anterior median fissure, forming what is termed the *pyramidal decussation.* Having crossed the middle line, they pass down in the posterior part of the lateral funiculus of the medulla spinalis as the lateral cerebrospinal fasciculus. The remaining fibres—i.e. those which occupy the lateral part of the pyramid—do not cross the middle line, but descend as the anterior cerebrospinal fasciculus (fig. 799) into the anterior funiculus of the same side of the medulla spinalis.

The greater part of the fasciculus proprius anterior of the medulla spinalis is continued upwards through the medulla oblongata under the name of the *medial longitudinal fasciculus.*

The **lateral region** of the medulla oblongata (fig. 800) is limited in front by the anterolateral sulcus and the roots of the hypoglossal nerve, and behind by the posterolateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves. Its upper part consists of a prominent oval mass which is named the olive, while its lower part is of the same width as the lateral funiculus of the medulla spinalis, and appears on the surface to be a direct continuation of it. As a matter of fact, only a portion of the lateral funiculus of the medulla spinalis is continued upwards into this region, for the lateral cerebrospinal fasciculus passes into the pyramid of the opposite side, and the direct cerebellar tract is carried into the restiform body in the posterior region. The remainder of the lateral funiculus, which consists chiefly of the fasciculus proprius lateralis and the superficial anterolateral fasciculus, can be traced into the lateral region of the medulla oblongata. Most of these fibres dip beneath the olive and disappear from the surface; but a small strand remains superficial, and ascends between the olive and the posterolateral sulcus. In a depression at the upper end of this strand is the acoustic nerve.

Fig. 799.—A scheme showing the passage of various fasciculi through the medulla oblongata. (Testut.)



a. Pons. *b.* Medulla oblongata. *c.* Decussation of the pyramids. *d.* Section of cervical part of medulla spinalis. 1. Anterior cerebrospinal fasciculus (in red). 2. Lateral cerebrospinal fasciculus (in red). 3. Fasciculus gracilis and fasciculus cuneatus (in blue). 3′. Nucleus gracilis and nucleus cuneatus. 4. Anterolateral proper fasciculus (in dotted line). 5. Pyramid. 6. Lemniscus. 7. Medial longitudinal fasciculus. 8. Superficial anterolateral fasciculus (in blue). 9. Direct cerebellar tract (in yellow).

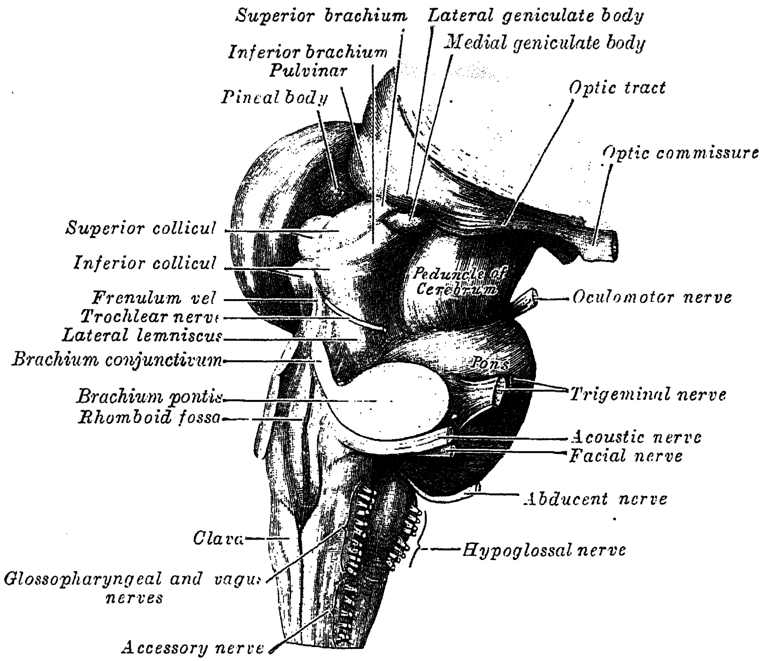
The *olive* is situated lateral to the pyramid, from which it is separated by the anterolateral sulcus and the fibres of the hypoglossal nerve. Behind, it is separated from the posterolateral sulcus by the small superficial strand of the lateral funiculus already referred to. It is about 1·25 cm. long, and between its upper end and the pons there is a slight depression to which the roots of the facial nerve are attached. The external arcuate fibres wind backwards across the lower part of the pyramid and olive and enter the restiform body.

The **posterior region** of the medulla oblongata (fig. 801) lies behind the posterolateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves, and, like the lateral region, is divisible into a lower and an upper portion.

The *lower part* is limited behind by the posterior median fissure, and consists of the *fasciculus gracilis* and the *fasciculus cuneatus*, the direct upward prolongations of the posterior funiculus of the medulla spinalis. The fasciculus gracilis is placed parallel to and along the side of the posterior median fissure, and is separated from the fasciculus cuneatus by the postero-intermediate sulcus and septum. The fasciculus gracilis and fasciculus cuneatus are at first

vertical; but at the lower part of the rhomboid fossa they diverge from the middle line in a V-shaped manner, and each presents an elongated swelling. The swelling on the fasciculus gracilis is named the *clava*, and is produced by a subjacent nucleus of grey substance, the *nucleus gracilis*; that on the fasciculus cuneatus is termed the *cuneate tubercle*, and is caused similarly by a grey nucleus, named the *nucleus cuneatus*. The fibres of these two fasciculi end by arborising around the cells in their respective nuclei. A third elevation, named the *tuberculum cinereum* (tubercle of Rolando), is present in the lower part of the posterior region of the medulla oblongata. It lies between the fasciculus cuneatus and the roots of the accessory nerve, and is narrow below but wider above; it ends superiorly at a distance of about 1·25 cm. below the pons. It is produced by a nucleus of grey substance which is continuous below with

FIG. 800.—The hind-brain and the mid-brain. Posterolateral aspect.



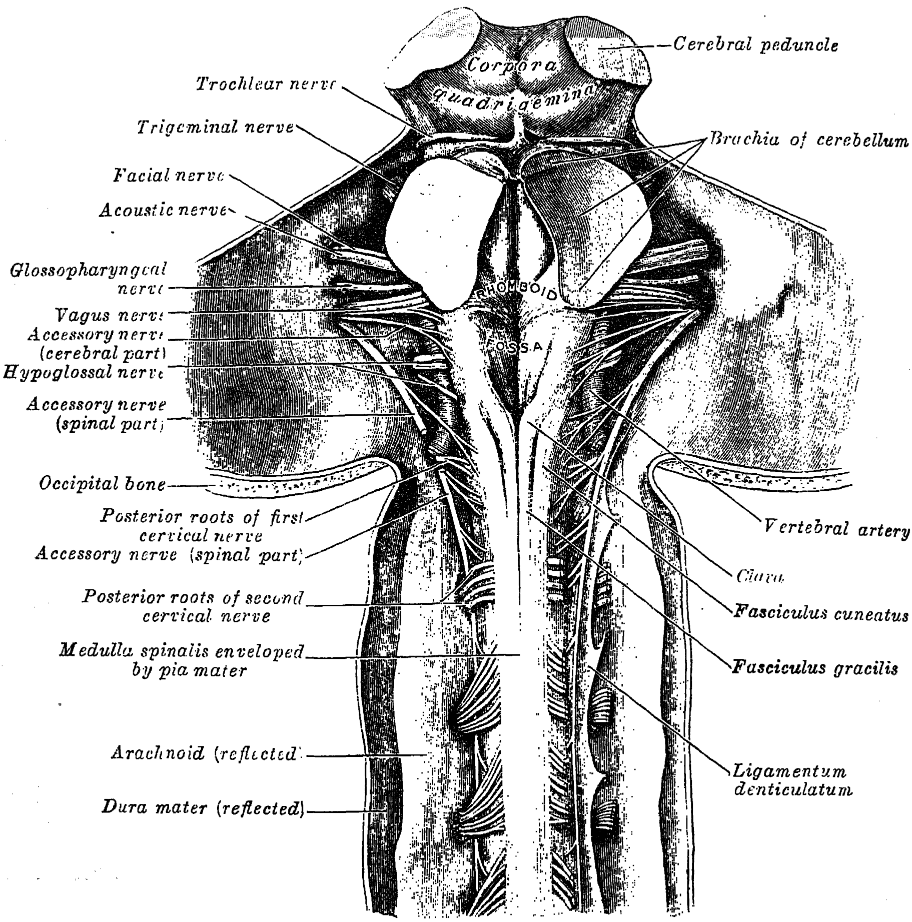
the substantia gelatinosa of Rolando, and in which the fibres of the tractus spinalis, or spinal root, of the trigeminal nerve ends; these fibres separate the nucleus from the surface of the medulla oblongata.

The *upper part* of the posterior region of the medulla oblongata is occupied by the *restiform body*, a thick rope-like strand situated between the lower part of the fourth ventricle and the roots of the glossopharyngeal and vagus nerves. The two restiform bodies connect the medulla spinalis and medulla oblongata with the cerebellum, and are sometimes named the *inferior peduncles of the cerebellum*. As they ascend, they diverge from one another, and assist in forming the lower parts of the lateral boundaries of the fourth ventricle; higher up, they are directed backwards, each passing to the corresponding cerebellar hemisphere. Near their entrance into the cerebellum they are crossed by several strands of fibres, which run to the median sulcus of the rhomboid fossa and are named the *striæ medullares*. The restiform body is not, although it appears to be, the upward continuation of the fasciculus gracilis and fasciculus cuneatus, since the fibres of these fasciculi end in the nucleus gracilis and nucleus cuneatus; its constitution will be subsequently discussed.

Internal structure of the medulla oblongata.—Although the external form of the medulla oblongata bears a certain resemblance to that of the upper part of the medulla spinalis, its internal structure differs widely from that of

the latter, and this for the following principal reasons: (1) certain fasciculi of nerve-fibres which extend from the medulla spinalis to the brain, or vice versa, undergo a rearrangement in their passage through the medulla oblongata; (2) other fasciculi of the medulla spinalis end in the medulla oblongata; (3) new fasciculi originate in the grey substance of the medulla oblongata and pass to different parts of the brain; (4) the grey substance, which in the medulla spinalis forms a continuous H-shaped column, is greatly modified and subdivided in the medulla oblongata, where also new masses of grey substance

FIG. 801.—The upper part of the medulla spinalis and the hind- and mid-brains. Exposed from behind.

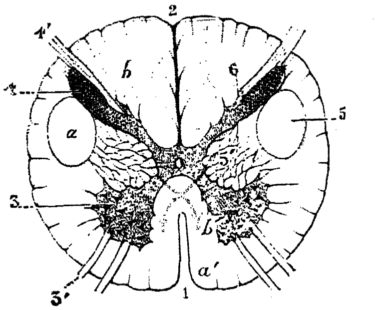


are added; (5) on account of the opening out of the central canal, certain parts of the grey substance, which in the medulla spinalis were more or less centrally situated, are displayed in the rhomboid fossa; (6) the medulla oblongata is intimately associated with many of the cerebral nerves, some arising from, and others ending in, nuclei within its substance. A short description of the course taken by the principal fasciculi, and of the arrangement of the grey substance, will now be given.

The **cerebrospinal fasciculi**.—The downward course of these fasciculi from the pyramids of the medulla oblongata and their partial decussation have already been described (p. 794). In crossing to the lateral funiculus of the opposite side, the fibres of the lateral cerebrospinal fasciculi run backwards through the anterior columns of grey substance, and separate the head of each of these columns from its base (figs. 802, 803). The base retains its

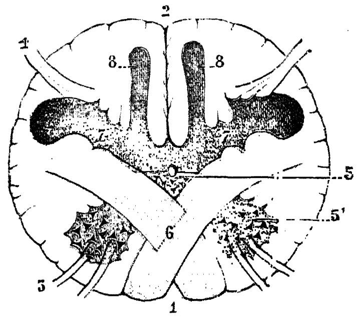
position in relation to the ventral aspect of the central canal, and, when the latter opens into the fourth ventricle, appears in the rhomboid fossa, or floor of the ventricle, close to the middle line, where it forms the nuclei of the hypoglossal and abducent nerves; while, above the level of the ventricle it exists as the nuclei of the trochlear and oculomotor nerves in relation to the floor of the cerebral aqueduct. The head of the column is pushed lateralwards and forms the *nucleus ambiguus* which gives origin from below upwards to the cerebral part of the accessory nerve and the motor fibres of the vagus and glosso-pharyngeal nerves: higher up, the head of the column is represented by the motor nuclei of the facial and trigeminal nerves.

FIG. 802.—A section through the medulla oblongata below the level of the decussation of the pyramids. Schematic. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3. Anterior column (in red), with 3', anterior root. 4. Posterior column (in blue), with 4', posterior root. 5. Lateral cerebrospinal fasciculus. 6. Posterior funiculus. The arrow, *a a'*, indicates the course of the decussation of the pyramids; the arrow, *b b'*, that of the decussation of the lemniscus.

FIG. 803.—A section through the medulla oblongata at the level of the decussation of the pyramids. Schematic. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3. Motor roots. 4. Sensory roots. 5. Base of the anterior column, from which the head (5') has been detached by the lateral cerebrospinal fasciculus. 6. Decussation of the pyramids. 7. Posterior columns (in blue). 8. Nucleus gracilis.

The **fasciculus gracilis and fasciculus cuneatus** constitute the posterior sensory fasciculi of the medulla spinalis; they are prolonged upwards into the lower part of the medulla oblongata, where they end in the nucleus gracilis and nucleus cuneatus. These two nuclei are continuous with the central grey substance of the medulla spinalis of which they may be regarded as dorsal projections, each being covered superficially by the fibres of the corresponding fasciculus. On transverse section, the nucleus gracilis appears as a single, more or less quadrangular mass, while the nucleus cuneatus consists of a larger *medial nucleus*, composed of small or medium-sized cells, and a smaller *lateral nucleus* containing large cells.

The fibres of the fasciculus gracilis and fasciculus cuneatus end by arborising around the cells of these nuclei (fig. 804). From the cells of the nuclei new fibres arise; some of these are continued as the external arcuate fibres into the restiform body of the same side, and through it to the cerebellum, but most of them pass forwards as the *internal arcuate fibres* through the neck of the posterior column, thus cutting off its head from its base (fig. 805). Curving forwards, they cross the middle line, and run upwards immediately behind the cerebrospinal fibres, as a flattened band, named the *lemniscus* or *fillet*. The crossing of these sensory fibres is situated above that of the motor fibres and reaches as high as the middle of the olive; it constitutes the *decussation of the lemniscus* or *sensory decussation*.

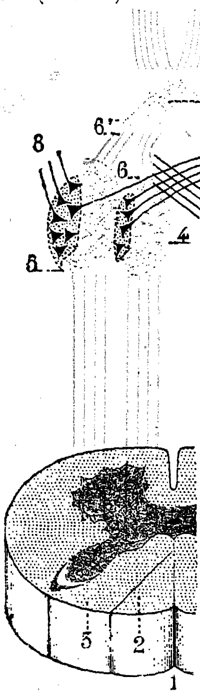
The base of the posterior column at first lies on the dorsal aspect of the central canal, but when the latter opens into the fourth ventricle, it appears in the lateral part of the rhomboid fossa. It forms the terminal nuclei of the sensory fibres of the vagus and glossopharyngeal nerves, and is associated with the vestibular part of the acoustic nerve and the sensory root of the facial nerve. Still higher, it forms a mass of pigmented cells—the *locus cœruleus*—in which some of the sensory fibres of the trigeminal nerve appear

to end. The head of the posterior column forms the tuberculum cinereum, a long nucleus, in which the fibres of the spinal tract of the trigeminal nerve largely end.

The **direct cerebellar tract** leaves the lateral region of the medulla oblongata; most of its fibres are carried backwards into the restiform body of the same side, and through it are conveyed to the cerebellum; but some run upwards with the fibres of the lemniscus, and, reaching the inferior colliculus, undergo decussation, and are carried to the cerebellum through the brachium conjunctivum.

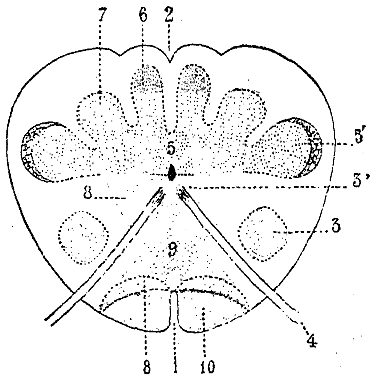
The **fasciculi proprii** (basis bundles) of the anterior and lateral funiculi of the medulla spinalis largely consist of intersegmental fibres, which link together its different segments; they assist in the production of the formatio reticularis of the medulla oblongata, and many of them are accumulated into a fasciculus which runs up close to the median raphe between the lemniscus and the rhomboid fossa; this strand is named the *medial longitudinal fasciculus*, and will be described more fully later (p. 827).

FIG. 804.—A scheme showing the superior terminations of the fasciculus gracilis and fasciculus cuneatus of the medulla spinalis. (Testut.)



1. Posterior median sulcus. 2. Fasciculus gracilis. 3. Fasciculus cuneatus. 4. Nucleus gracilis. 5. Nucleus cuneatus. 6, 6′, 6″, Sensory fibres forming the lemniscus. 7. Sensory decussation. 8. Cerebellar fibres, uncrossed. 9. Cerebellar fibres, crossed.

FIG. 805.—A transverse section through the sensory decussation (decussation of the lemniscus). Schematic. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3, 3′. Head and base of the anterior column (in red). 4. Hypoglossal nerve. 5. Bases of the posterior columns. 5′. Tuberculum cinereum (tubercle of Rolando). 6. Nucleus gracilis. 7. Nucleus cuneatus. 8, 8. Lemniscus. 9. Sensory decussation. 10. Pyramid.

Grey substance of the medulla oblongata (figs. 806, 807).—In addition to the gracile and cuneate nuclei, there are several other nuclei to be considered. Some of these are traceable from the grey substance of the medulla spinalis, while others are unrepresented in it.

1. The *hypoglossal nucleus* is derived from the base of the anterior column; in the lower, closed part of the medulla oblongata it is situated on the ventrolateral aspect of the central canal, but in the upper, open part it approaches the rhomboid fossa, where it lies close to the middle line, under an eminence named the *trigonum hypoglossi* (fig. 821). The nucleus measures about 2 cm. in length, and consists of large multipolar nerve-cells the axons of which constitute the roots of the hypoglossal nerve. These nerve-roots pass forward between the anterior and lateral regions of the medulla oblongata, and emerge at the anterolateral sulcus.

2. The *motor nucleus* (figs. 808, 809) common to the *glossopharyngeal*, *vagus*, and cerebral part of the *accessory* nerves is named the *nucleus ambiguus*. It

FIG. 806.—A transverse section through the medulla oblongata at about the middle of the olive. (Schwalbe.)

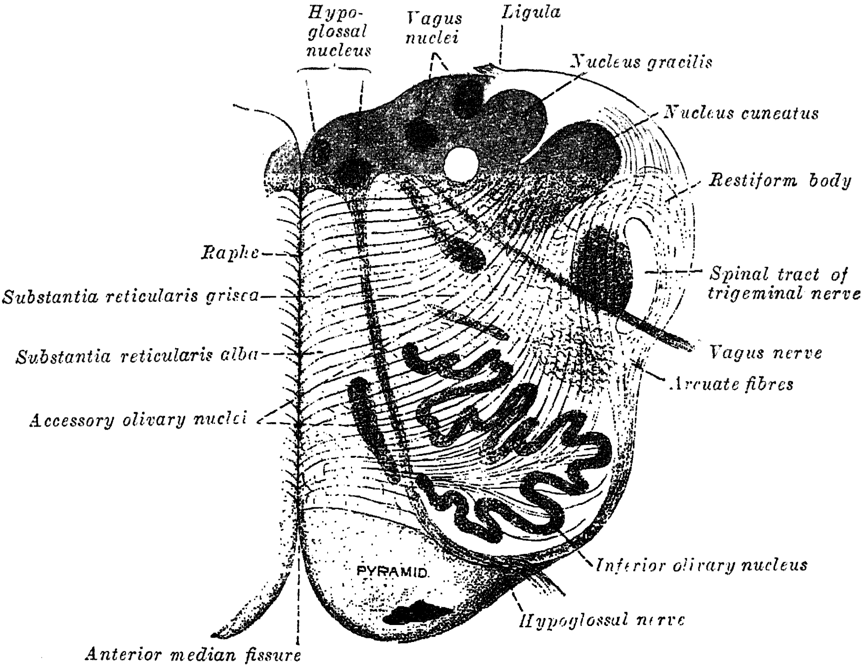
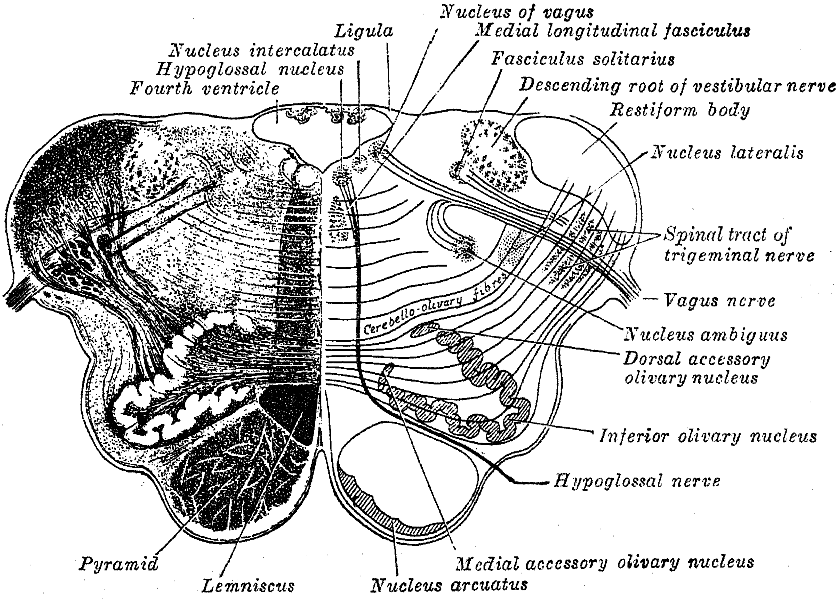


FIG. 807.—A transverse section through the medulla oblongata below the middle of the olive.



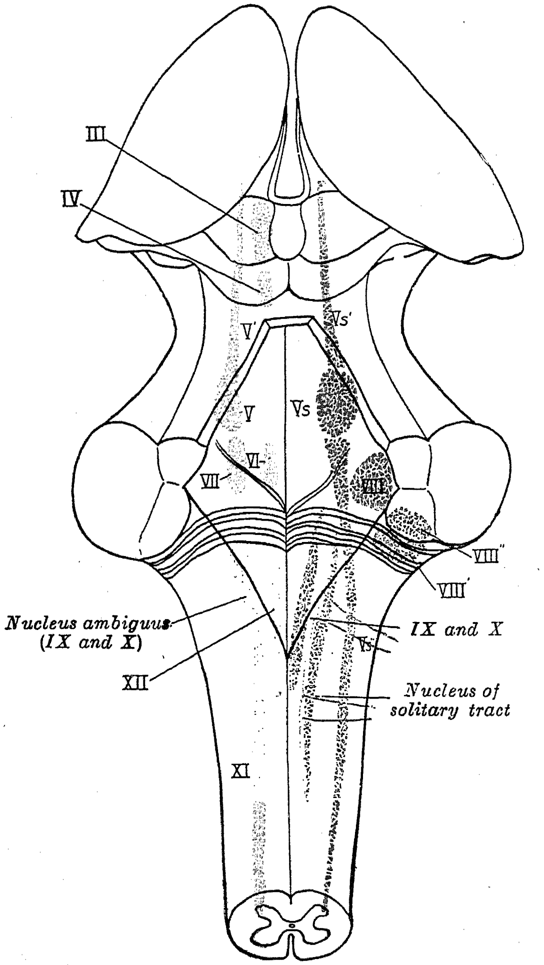
lies deeply in the formatio reticularis grisea, and extends throughout nearly the whole length of the medulla oblongata.

3. The afferent fibres of the *facial, glossopharyngeal* and *vagus* end in the fasciculus solitarius (p. 811).

4. The *nuclei of the acoustic nerve* are described on p. 814.

5. The *olivary nuclei* (figs. 806, 807) are three in number on either side of the middle line, viz. the inferior olivary nucleus, and the medial and dorsal accessory olivary nuclei; they consist of small, round, yellowish cells and numerous fine nerve-fibres. (*a*) The *inferior olivary nucleus* is the largest, and is situated within the olive. It consists of a grey folded lamina arranged in the form of an incomplete capsule, opening medially by an aperture called the *hilum*; emerging from the hilum are numerous fibres which collectively constitute the *peduncle of the olive.* (*b*) The *medial accessory olivary nucleus* lies between the inferior olivary nucleus and the pyramid, and forms a curved lamina, the concavity of which is directed laterally. The fibres of the hypoglossal nerve, as they traverse the medulla, pass between the medial accessory and the inferior olivary nuclei. (*c*) The *dorsal accessory olivary nucleus* is the smallest, and appears on transverse section as a curved lamina behind the inferior olivary nucleus.

Fig. 808.—The nuclei of the cerebral nerves schematically represented. Dorsal aspect. Motor nuclei, in red; sensory in blue. (The olfactory and optic centres are omitted.)



The inferior olivary nucleus is connected—(1) with that of the opposite side by fibres which cross through the raphe; (2) with the anterior column of the same side of the medulla spinalis by the *spino-olivary fasciculus*; (3) with the thalamus of the cerebrum by the *cerebro-olivary fasciculus* which passes through the pons and tegmentum; (4) with the opposite cerebellar hemisphere by the *olivo-cerebellar fasciculus* (fig. 811), the fibres of which cross the raphe and turn backwards to enter the deep part of the restiform body. Removal of one cerebellar hemisphere is followed by atrophy of the opposite olivary nucleus.

6. The *nucleus arcuatus* is described with the external arcuate fibres (p. 811).

Restiform bodies.—The position of the restiform bodies has already been described (p. 803). Each comprises: (1) the direct cerebellar tract or posterior spino-cerebellar fasciculus, which ascends from the lateral funiculus of the same side of the medulla spinalis; (2) the olivo-cerebellar fasciculus, described above; (3) descending cerebellar fibres, many of which are disseminated throughout the peripheral part of the anterior and lateral funiculi of the medulla spinalis, while others pass to the motor nuclei of the cerebral nerves; and (4) the external arcuate fibres.

FIG. 809.—The nuclei of origin of the cerebral motor nerves schematically represented. Lateral aspect.

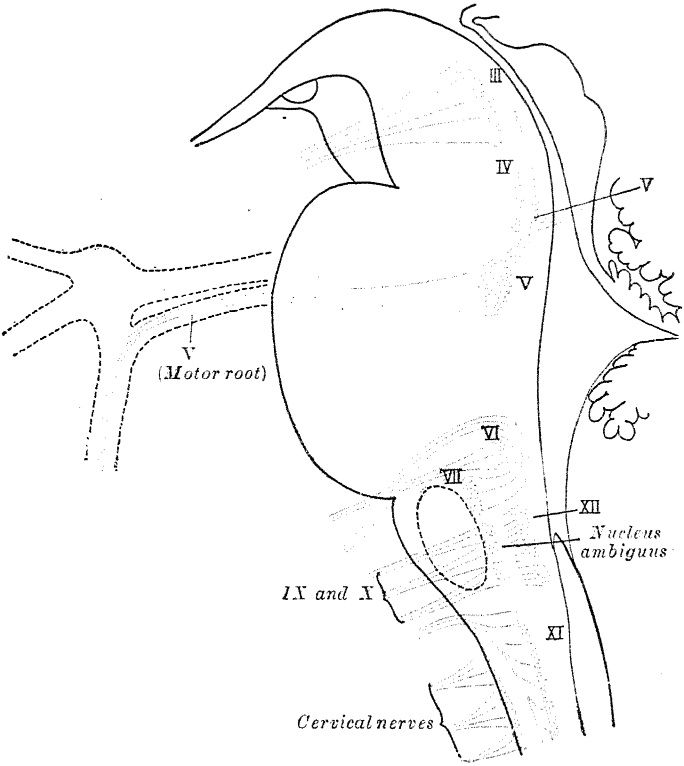
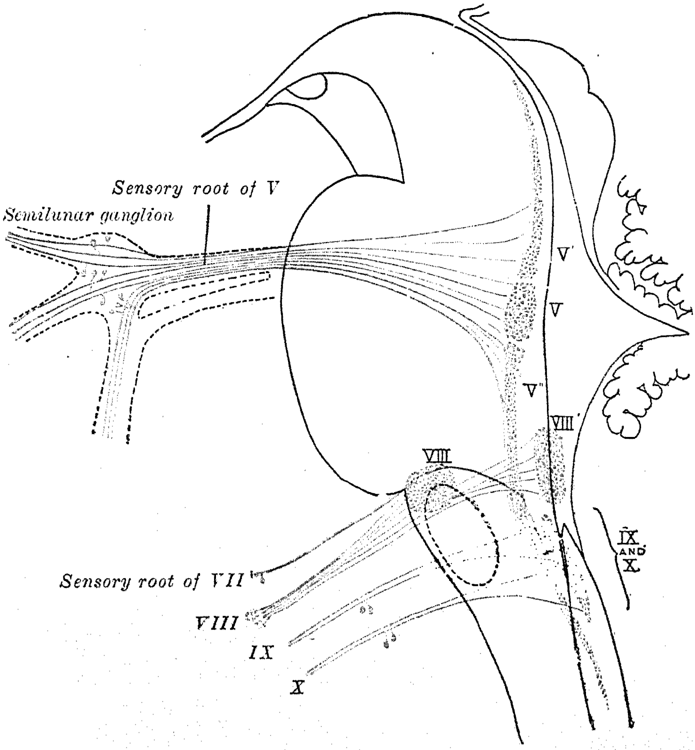


FIG. 810.—The primary terminal nuclei of the afferent (sensory) cerebral nerves schematically represented. Lateral aspect. (The olfactory and optic centres are omitted.)



The *lymphatic vessels of the anus* pass forwards and end with those of the skin of the perinæum and scrotum in the superficial inguinal lymph-glands.

The *lymphatic vessels of the anal canal and rectum.*—The lymphatic vessels of the *anal canal* accompany the inferior hæmorrhoidal vessels across the ischiorectal fossa, run with the internal pudendal vessels through Alcock's canal, and open into the hypogastric (internal iliac) lymph-glands. The lymphatic vessels from the *lower part of the rectum* join in a plexus on the Levator ani, and then enter the hypogastric lymph-glands; those from the *upper part of the rectum* accompany the superior hæmorrhoidal vessels, and, after traversing the pararectal lymph-glands, enter the lymph-glands near the bifurcation of the common iliac artery; vessels pass from the highest pararectal lymph-glands to the lymph-glands in the sigmoid mesocolon, and the efferents of the latter glands end in the pre-aortic lymph-glands around the origin of the inferior mesenteric artery.

The *lymphatic vessels of the liver* are divisible into two sets, superficial and deep. The former arise in the subperitoneal areolar tissue over the entire surface of the organ, and may be grouped into: (*a*) those on the convex surface, (*b*) those on the inferior surface.

(*a*) On the *convex surface.*—The vessels from the back part of this surface reach their terminal lymph-glands by three different routes: the vessels of the middle set, five or six in number, pass through the vena-caval foramen in the Diaphragm and end in one or two lymph-glands which are situated around the terminal part of the inferior vena cava; a few vessels from the left side pass backwards towards the œsophageal hiatus, and terminate in the paracardial group of superior gastric lymph-glands; the vessels from the right side, one or two in number, run on the abdominal surface of the Diaphragm, and, after crossing its right crus, end in the pre-aortic lymph-glands which surround the origin of the cœliac artery. From the portions of the right and left lobes adjacent to the falciform ligament, the lymphatic vessels converge to form two trunks, one of which accompanies the inferior vena cava through the Diaphragm, and ends in the lymph-glands around the terminal part of this vessel; the other runs downwards and forwards, and, turning round the anterior sharp margin of the liver, accompanies the upper part of the ligamentum teres, and ends in the upper hepatic lymph-glands. From the anterior surface a few additional vessels turn round the anterior sharp margin to reach the upper hepatic lymph-glands.

(*b*) On the *inferior surface.*—The vessels from this surface mostly converge to the porta hepatis, and accompany the deep lymphatics emerging from the porta to the hepatic lymph-glands; one or two from the posterior parts of the right and caudate lobes accompany the inferior vena cava through the Diaphragm, and end in the lymph-glands round the terminal part of this vein.

The deep lymphatics of the liver converge to ascending and descending trunks. The ascending trunks accompany the hepatic veins and pass through the Diaphragm to end in the lymph-glands round the terminal part of the inferior vena cava. The descending trunks emerge from the porta hepatis, and end in the hepatic lymph-glands.

The *lymphatic vessels of the gall-bladder* pass to the cystic lymph-gland and to the hepatic lymph-glands in the porta hepatis; those of the *bile-duct* to the hepatic lymph-glands alongside the bile-duct and to the upper pancreaticoduodenal lymph-glands.

The *lymphatic vessels of the pancreas* follow the course of its blood-vessels. Most of them enter the pancreaticolienal lymph-glands, but some end in the pancreaticoduodenal lymph-glands, and others in the pre-aortic lymph-glands near the origin of the superior mesenteric artery.

(2) The *lymphatic vessels of the spleen and suprarenal glands.*

The *lymphatic vessels of the spleen*, both superficial and deep, accompany the splenic blood-vessels and pass to the pancreaticolienal lymph-glands.

The *lymphatic vessels of the suprarenal glands* usually accompany the suprarenal veins, and end in the lateral aortic lymph-glands; occasionally some of them pierce the crura of the Diaphragm, and end in the lymph-glands of the posterior mediastinal cavity.

(3) The *lymphatic vessels of the urinary organs.*

The *external arcuate fibres* vary as to their prominence in different brains ; in some they form an almost continuous layer covering the pyramid and olive, while in others they are barely visible on the surface. They arise from the cells of the nucleus gracilis and nucleus cuneatus, pass forwards through the formatio reticularis, and decussate in the middle line. Most of them reach the surface by way of the anterior median fissure, and arch backwards over the pyramid. Reinforced by others which emerge between the pyramid and olive, they pass backwards over the olive and lateral region of the medulla oblongata, and enter the restiform body. They thus connect the cerebellum with the nucleus gracilis and nucleus cuneatus of the opposite side. As the fibres arch across the pyramid, they enclose a small nucleus which lies in front of and medial to the pyramid. This is named the *nucleus arcuatus*, and is serially continuous above with the nuclei pontis : it contains small fusiform cells, around which some of the arcuate fibres end, and from which others arise.

A few fibres are said to arise from the nucleus gracilis and nucleus cuneatus and to pass to the restiform body of the same side.

Formatio reticularis (fig. 812).—This term is applied to the coarse reticulum which occupies the anterior and lateral regions of the medulla oblongata. It is situated behind the pyramid and olive, extending laterally as far as the restiform bodies, and dorsally to within a short distance of the rhomboid fossa. The reticulum is caused by the intersection of bundles of fibres running at right angles to each other, some being longitudinal, others more or less transverse in direction. In the formatio reticularis of the anterior region, there is an almost entire absence of nerve-cells, and hence this part is known as the *substantia reticularis alba*; whereas in the lateral region nerve-cells are numerous, and as a consequence the formatio presents a grey appearance, and is termed the *substantia reticularis grisea.*

In the substance of the formatio reticularis are two small nuclei of grey matter: one, the *nucleus of Roller*, near the ventral surface of the hypoglossal nucleus; the other, the *nucleus lateralis*, between the olive and the spinal tract of the trigeminal nerve.

In the substantia reticularis alba the chief longitudinal fibres consist of the *lemniscus*, which lies close to the raphe, immediately behind the pyramid; the *tectospinal fasciculus*, behind the lemniscus; and still more posteriorly, the *medial longitudinal fasciculus*. In the substantia reticularis grisea the ascending fibres comprise the *spinocerebellar*, *spinothalamic*, and *spinotectal fasciculi*; the descending fibres include the *rubrospinal* and *thalamo-olivary fasciculi*, and the *fasciculus solitarius*, the last consisting of the downwardly directed afferent fibres of the facial, vagus and glosso-pharyngeal nerves. The transverse fibres of the formatio reticularis are the arcuate fibres already described (p. 805, and above).

Applied Anatomy.—In *bulbar paralysis*, i.e. paralysis of the medulla oblongata, which is really a special form of a progressive degeneration affecting the whole efferent or motor tract, the disease begins with impairment of the movements of the lips, tongue, pharynx, and larynx, due to degeneration of the cells in the motor nuclei of the medulla oblongata. Speech and swallowing become difficult, and the saliva dribbles from the open mouth. Other groups of muscles soon become involved, and death often occurs from ‘aspiration pneumonia,’ set up by food that has accidentally passed down the trachea.

The Pons

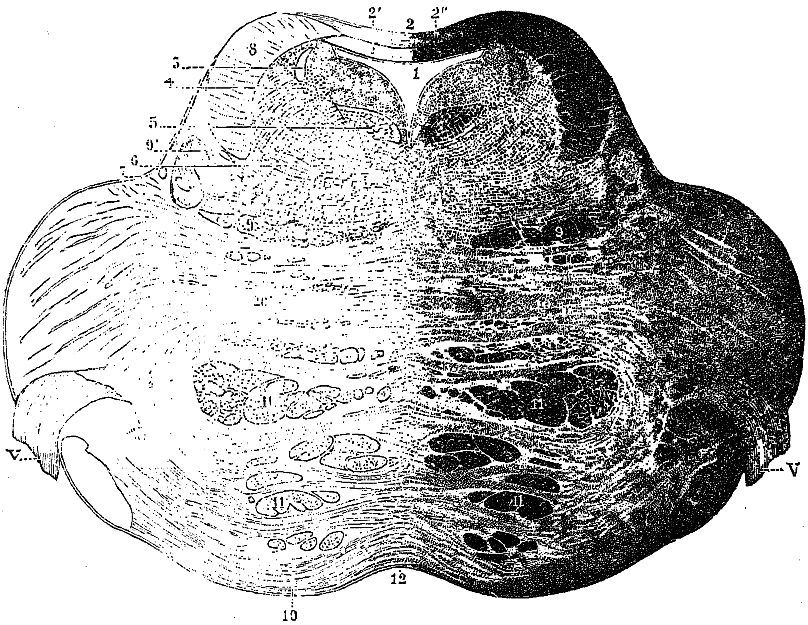
The **pons** (pons Varolii) or fore part of the rhombencephalon is situated in front of the cerebellum. From its upper part the cerebral peduncles emerge, one on either side of the middle line. Behind and below, the pons is continuous with the medulla oblongata, but is separated from it in front and laterally by a transverse furrow in which the abducent, facial, and acoustic nerves appear.

Its *ventral or anterior surface* (fig. 798) is prominent, markedly convex from side to side, less so from above downwards. It consists of transverse fibres arched like a bridge across the middle line, and gathered on either side into a compact mass which forms the brachium pontis. It rests upon the clivus of

the sphenoidal bone, and is limited above and below by well-defined borders. In the middle line is the shallow *sulcus basilaris* for the lodgment of the basilar artery ; this sulcus is bounded on either side by an eminence caused by the descent of the cerebrospinal fibres through the substance of the pons. Lateral to these eminences, near the upper border of the pons, the trigeminal nerves make their exit, each consisting of a smaller, medial, motor root, and a larger, lateral, sensory root ; vertical lines drawn immediately lateral to the attachments of the trigeminal nerves, may be taken as the boundaries between the ventral surface of the pons and the brachia pontis.

Its *dorsal or posterior surface,* triangular in shape, is hidden by the cerebellum, and is bounded laterally by the brachia conjunctiva ; it forms the upper part of the rhomboid fossa, with which it will be described.

Fig. 813.—A coronal section through the upper part of the pons. (Testut.)



1. Fourth ventricle ; its ependyma is coloured yellow. 2. Anterior medullary velum, with 2′, its white stratum, and 2″, its grey stratum. 3. Mesencephalic root of trigeminal nerve. 4. Nerve-cells associated with this root. 5. Medial longitudinal fasciculus. 6. Formatio reticularis. 7. Lateral sulcus. 8. Section of brachium conjunctivum. 9. Medial lemniscus. 9′. Lateral lemniscus. 10, 10. Transverse fibres of pons. 11, 11. Cerebrospinal fasciculi. 12. Raphe. V. Trigeminal nerve.

Structure (fig. 813).—Transverse sections through the pons show it to be composed of two parts ; a ventral or basilar portion consisting for the most part of fibres arranged in transverse and longitudinal bundles, together with a small amount of grey substance ; and a dorsal or tegmental portion continuous with the reticular formation of the medulla oblongata, and most of the constituents of which are prolonged into the tegmenta of the cerebral peduncles.

The *ventral or basilar part* of the pons consists of : (*a*) superficial and deep transverse fibres, (*b*) longitudinal fasciculi, and (*c*) some small nuclei of grey substance termed the nuclei pontis.

The *superficial transverse fibres* constitute a rather thick layer on the ventral surface of the pons, and are collected into a large rounded bundle on either side. This bundle, with the addition of some transverse fibres from the deeper portion of the pons, forms the greater part of the brachium pontis.

The *deep transverse fibres* partly intersect and partly lie on the dorsal aspect of the longitudinal fasciculi. They course to the lateral border of the pons, and form part of the brachium pontis ; the further connexions of the brachium pontis will be discussed with the anatomy of the cerebellum.

The *longitudinal fasciculi* are continued from the cerebral peduncles, and enter the upper surface of the pons. They stream downwards on either side of the middle line in bundles, separated from one another by the deep transverse fibres, and give rise to the eminences on the anterior surface. Some of these fibres end in the nuclei pontis, and others, after decussating, in the nuclei of the abducent and hypoglossal nerves, and in the motor nuclei of the trigeminal and facial nerves; but many pass through the pons, at the lower margin of which they are collected into the pyramids of the medulla oblongata. The fibres which end in the motor nuclei of the cerebral nerves are derived from the pyramidal cells of the cerebral cortex, and bear the same relation to the motor cells of the cerebral nerves as the cerebrospinal fibres bear to the motor cells in the anterior column of the medulla spinalis.

The *nuclei pontis* are serially continuous with the arcuate nuclei in the medulla oblongata, and consist of small groups of multipolar nerve-cells which are scattered between the bundles of transverse fibres; the axons of these cells are continuous with the transverse fibres of the pons.

The *dorsal or tegmental part* of the pons is chiefly composed of an upward continuation of the reticular formation and grey substance of the medulla oblongata; it is divided by a median raphe. It consists of transverse and longitudinal fibres and contains important grey nuclei. In the lower part of the pons the transverse fibres of the tegmental part are collected into a strand, named the *trapezoid body*. This consists of fibres which arise from the cells of the ventral or accessory cochlear nucleus and of the superior olivary nucleus, and will be referred to in connexion with the cochlear division of the acoustic nerve. In the substance of the trapezoid body is a collection of nerve-cells, termed the *trapezoid nucleus*. Of the longitudinal fibres three fasciculi must be mentioned. They are (*a*) the upward prolongation of the *lemniscus* which, as it ascends, assumes the form of a flat band; (*b*) the *medial longitudinal* fasciculus, situated near the floor of the fourth ventricle; and (*c*) the *anterior* spinocerebellar fasciculus which passes to the cerebellum by way of the brachium conjunctivum.

The rest of the dorsal part of the pons is a continuation upwards of the formatio reticularis of the medulla oblongata, and, like it, presents the appearance of a network, in the meshes of which are numerous nerve-cells. Besides these scattered nerve-cells, there are some larger masses of grey substance, viz. the superior olivary nucleus, and the nuclei of the trigeminal, abducent, facial, and acoustic nerves (fig. 808).

1. The *superior olivary nucleus* is a small mass of grey substance situated on the dorsal surface of the lateral part of the trapezoid body. Rudimentary in man, but well developed in certain animals, it exhibits the same structure as the inferior olivary nucleus, and is situated immediately above it. Some of the fibres of the trapezoid body end by arborising around the cells of the superior olivary nucleus, while others arise from these cells.

2. The *nuclei of the trigeminal nerve* in the pons are motor and sensory. The *inferior or chief motor nucleus* is situated in the upper part of the pons close to its posterior surface and along the line of the lateral margin of the fourth ventricle. The axons of its cells form a portion of the motor root of the trigeminal nerve: the remaining fibres of the motor root of this nerve consist of a fasciculus which arises from a nucleus in the grey substance of the floor of the cerebral aqueduct, and hence is named the *mesencephalic root.** The sensory fibres of the trigeminal nerve arise from the cells of the semilunar ganglion. Some of these fibres end in a nucleus which is placed lateral to the motor one, and beneath the brachium conjunctivum; but the greater number descend, under the name of the *spinal tract of the trigeminal nerve*, to end in a nucleus which is continuous below with the substantia gelatinosa of Rolando. The motor and sensory roots of the trigeminal nerve pass through the substance of the pons and emerge near the upper margin of its anterior surface.

3. The *nucleus of the abducent nerve* is a spherical mass of grey substance situated close to the floor of the fourth ventricle, above the striæ medullares and subjacent to the colliculus facialis. The fibres of the abducent nerve pass forward through the entire thickness of the pons on the medial side of the superior olivary nucleus and between the lateral fasciculi of the cerebrospinal

* See footnote on p. 893.

fibres, and emerge in the furrow between the lower border of the pons and the pyramid of the medulla oblongata.

4. The *nucleus of the facial nerve* is situated deeply in the reticular formation of the pons on the dorsal aspect of the superior olivary nucleus, and the roots of the nerve derived from it pursue a remarkably tortuous course in the substance of the pons. At first they pass backwards and medialwards until they reach the rhomboid fossa, close to the median sulcus, where they are collected into a round bundle; this bundle passes upwards and forwards, producing an elevation, the *colliculus facialis*, in the rhomboid fossa, and then taking a sharp lateral bend round the nucleus of the abducent nerve, passes through the pons to emerge at its lower border in the interval between the olive and the restiform body of the medulla oblongata.

5. The *nuclei of the acoustic nerve*.—The acoustic nerve consists of a cochlear and a vestibular nerve. The fibres of the cochlear nerve end in two nuclei: (*a*) the *lateral cochlear nucleus*, on the lateral surface of the restiform body; and (*b*) the *ventral or accessory cochlear nucleus*, on the ventral surface of the restiform body. The nuclei in which the vestibular nerve ends are (*a*) the *medial or chief vestibular nucleus*, corresponding to the lower part of the area acustica in the rhomboid fossa; the caudal end of this nucleus is termed (*b*) the *descending or spinal vestibular nucleus*; (*c*) the *lateral vestibular nucleus* (nucleus of Deiters), consisting of large multipolar cells and situated in the lateral angle of the rhomboid fossa; the dorsolateral part of this nucleus is sometimes termed (*d*) the *superior vestibular nucleus* (nucleus of Bechterew).

Applied Anatomy.—Injury to the pons, such as may occur on the occlusion or rupture of one of its blood-vessels, often gives rise to a special train of symptoms that is almost diagnostic. Pontine lesions are characterised mainly by 'alternate paralyses'; that is to say, by paralysis of the muscles supplied by one of the motor cerebral nerves on one side, and of the limbs on the other side of the body. Thus a hæmorrhage into the lower part of the pons might cause paralysis of the face ('lower segment paralysis') on the same side, from destruction of the facial nucleus or nerve-root, and paralysis of the arm and leg on the opposite side from injury to the adjacent cerebrospinal tract. In the same way, paralysis of the Rectus lateralis of one eye and of the Rectus medialis of the other ('conjugate paralysis' of the muscles turning the two eyes in one direction) and often paralysis of one side of the face as well, together with palsy of the limbs on the opposite side of the body, may be found when the lesion occurs about the nucleus of the abducent nerve. Hearing is often unaffected in pontine lesions, possibly because the central acoustic tract occupies a ventral and lateral position in the pons.

The Cerebellum

The **cerebellum**, the largest part of the hind-brain, lies behind the pons and medulla oblongata. Between its central portion and these structures is the cavity of the fourth ventricle. It rests on the inferior fossæ of the occipital bone and is covered by the tentorium cerebelli (p. 879). It is somewhat ovoid in form, but constricted in its median part, and flattened from above downwards, its greatest diameter being from side to side. Its surface is not convoluted like that of the cerebrum, but is traversed by numerous curved furrows or sulci, which vary in depth at different parts, and separate the laminæ of which it is composed. Its average weight in the male is about 150 gms. In the adult the proportion between the cerebellum and cerebrum is about 1 to 8, in the infant about 1 to 20.

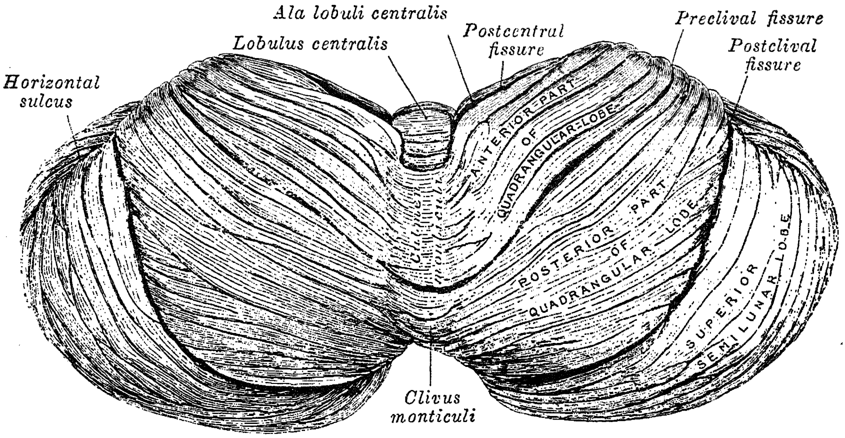
Lobes of the cerebellum.—The cerebellum consists of a median constricted part, the *vermis*, and two lateral expanded portions, the *hemispheres*. On the upper surface of the cerebellum the vermis is elevated above the level of the hemispheres, but on the under surface it is sunk almost out of sight in a deep depression between them; this depression is called the *vallecula cerebelli*, and lodges also the posterior part of the medulla oblongata. The part of the vermis on the upper surface of the cerebellum is named the *superior vermis*; that on the lower surface, the *inferior vermis*. The hemispheres are separated below and behind by a deep notch, the *posterior cerebellar notch*, and in front by a broader, shallower notch, the *anterior cerebellar notch*. The posterior notch contains the upper part of the falx cerebelli, a fold of dura mater. The anterior notch lies close to the pons and upper part of the

medulla, and its superior edge curves round the inferior colliculi and the brachia conjunctiva cerebelli.

The cerebellum is characterised by its laminated or foliated appearance; it is marked by curved fissures, which extend for a considerable distance into its substance, and divide it into a series of layers or folia. The largest and deepest fissure is named the *horizontal sulcus.* On either side it commences in front at the pons, and passes horizontally round the free margin of the hemisphere to the middle line behind; it divides the cerebellum into an upper and a lower portion. Several secondary but deep fissures separate the cerebellum into lobes, and these are further subdivided by shallower sulci, which separate the individual folia or laminæ from each other. Sections across the laminæ show that the folia consist of central white substance covered by grey substance.

The cerebellum is connected to the cerebrum by the brachia conjunctiva, to the pons by the brachia pontis, and to the medulla oblongata by the restiform bodies.

FIG. 814.—The cerebellum. Superior aspect. (Sharpey Schafer.)



The **superior surface of the cerebellum** (fig. 814) presents a raised median ridge, the superior vermis, which is not sharply defined from the hemispheres.

The superior vermis, most prominent in front, is subdivided from before backwards into the lingula, the lobulus centralis, the monticulus, and the folium vermis, and each of these with the exception of the lingula, is continuous with corresponding parts of the hemispheres—the lobulus centralis with the alæ, the monticulus with the quadrangular lobules, and the folium vermis with the superior semilunar lobules.

The **lingula** is a small tongue-shaped process, consisting of four or five folia; it lies in front of and is concealed by the lobulus centralis. It rests on the dorsal surface of the anterior medullary velum, and its white substance is continuous with that of the velum.

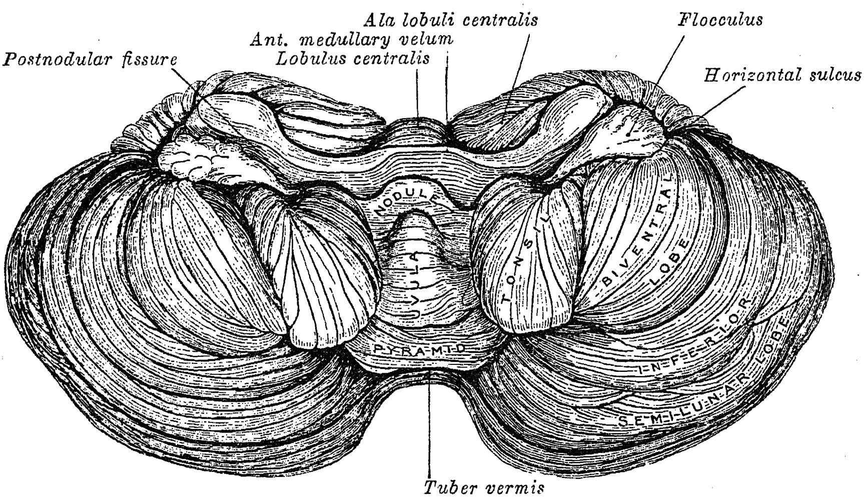
The **lobulus centralis and alæ.**—The lobulus centralis is a small square lobule situated in the anterior cerebellar notch. It overlaps the lingula, but is separated from it by the *precentral fissure*; laterally, it is continued into each hemisphere, as a wing-like prolongation, the *ala lobuli centralis.*

The **monticulus and quadrangular lobules.**—The monticulus is the largest part of the superior vermis. Anteriorly, it overlaps the lobulus centralis from which it is separated by the *postcentral fissure*; laterally, it is continuous with the *quadrangular lobules* in the hemispheres. It is divided by the *preclival fissure* (fissura prima) into an anterior, raised part, the *culmen* or summit, and a posterior sloped part, the *clivus*: the quadrangular lobule is similarly divided. The culmen and the anterior parts of the quadrangular lobules form the *lobus culminis*; the clivus and the posterior parts, the *lobus clivi.*

The folium vermis and superior semilunar lobules.—The folium vermis (folium cacuminis) is a short, narrow, concealed band at the posterior end of the superior vermis, consisting apparently of a single folium, but in reality marked on its upper and under surfaces by secondary fissures. Laterally, it expands in either hemisphere into a considerable lobule, the *superior semilunar lobule*, which occupies the posterior one-third of the upper surface of the hemisphere, and is bounded below by the *horizontal sulcus*. The folium vermis and the superior semilunar lobules form the *lobus semilunaris*.

The **inferior surface of the cerebellum** (fig. 815) presents, in the middle line, the *inferior vermis*, buried in the vallecula, and separated from the hemisphere on either side by a deep groove, the *sulcus valleculæ*. This surface, like the superior, is divided into lobules; but the arrangement is more complicated, and the relations of the parts of the vermis to those of the hemispheres are less clearly marked. The inferior vermis is subdivided from before backwards, into: (1) the *nodule*, (2) the *uvula*, (3) the *pyramid*, and (4) the *tuber*

FIG. 815.—The cerebellum. Interior aspect. (Sharpey Schaffer.)



vermis; the corresponding parts in either hemisphere are: (1) the *flocculus*, (2) the *tonsilla cerebelli*, (3) the *biventral lobule*, and (4) the *inferior semilunar lobule*. The three main fissures are: (1) the *postnodular fissure*, which runs transversely across the vermis, between the nodule and the uvula; in the hemispheres this fissure passes in front of the tonsilla and the biventral lobe but behind the flocculus, and joins the anterior end of the horizontal sulcus. (2) The *prepyramidal fissure* crosses the vermis between the uvula and the pyramid, then curves forwards between the tonsilla and the biventral lobe, to join the postnodular fissure. (3) The *postpyramidal fissure* passes across the vermis between the pyramid and the tuber vermis, and, in the hemisphere, courses behind the tonsilla and biventral lobule, and then along the lateral border of the biventral lobule to the postnodular sulcus; in the hemisphere it forms the anterior boundary of the inferior semilunar lobule.

The **nodule, posterior medullary velum and flocculus.**—The nodule, or anterior end of the inferior vermis, abuts against the roof of the fourth ventricle, and can only be distinctly seen after the cerebellum has been separated from the medulla oblongata and pons. On either side of the nodule is a thin layer of white substance, named the *posterior medullary velum* (p. 817). The flocculus is a prominent, irregular lobule, situated in front of the biventral lobule, between it and the brachium pontis cerebelli. It is subdivided into a few small laminæ, and is connected to the posterior medullary velum by its central white core. The flocculi, nodule, and posterior medullary velum constitute the *lobus noduli*.

The **uvula and tonsillæ**.—The uvula forms a considerable portion of the inferior vermis; it is separated on either side from the tonsilla by the *sulcus valleculæ*, at the bottom of which it is connected to the tonsilla by a furrowed ridge of grey matter called the *furrowed band*. The tonsillæ are rounded masses, situated in the hemispheres. Each lies in a deep fossa, termed the *bird's nest* (nidus avis), between the uvula and the biventral lobule. The uvula and tonsillæ form the *lobus uvulæ*.

The **pyramid and biventral lobules** constitute the *lobus pyramidalis*. The pyramid, a conical projection, is the largest prominence of the inferior vermis. It is separated from the hemispheres by the sulcus valleculæ, across which it is connected to the biventral lobule by an indistinct grey band, analogous to the furrowed band already described. The biventral lobule is somewhat ovoid in shape; its narrower end points backwards, and is joined by the grey band to the pyramid; its broader end, directed forwards, is on a line with the anterior border of the tonsilla, and is separated from the flocculus by the postnodular fissure. The lateral border is separated from the inferior semilunar lobule by the postpyramidal fissure.

The **tuber vermis and the inferior semilunar lobules** form the *lobus tuberis*. The tuber vermis, the most posterior division of the inferior vermis, is of small size, and spreads out laterally into the large inferior semilunar lobules, which comprise at least two-thirds of the inferior surface of the hemisphere.

The **anterior medullary velum** (valve of Vieussens) is a thin, transparent lamina of white substance, which stretches between the brachia conjunctiva, and with them forms the roof of the upper part of the fourth ventricle. The velum is narrow above, where it passes beneath the inferior colliculi, and broader below, where it is continuous with the white substance of the superior vermis. The folia of the lingula are prolonged on to the dorsal surface of its lower half, and a median ridge, the *frenulum veli*, descends upon its upper part from between the inferior colliculi. The trochlear nerves emerge from the sides of the frenulum.

The **posterior medullary velum** is a thin layer of white substance, situated above and on either side of the nodule; it forms a part of the roof of the fourth ventricle, and its deep surface is covered by the ventricular epithelium. Somewhat semilunar in shape, its upper convex edge is continuous with the white substance of the cerebellum, while its lower concave margin is free; from it the ventricular epithelium is prolonged downwards to the tæniæ of the ventricle.

The two medullary vela are in contact with each other along their line of emergence from the white substance of the cerebellum; and this line of contact forms the summit of the roof of the fourth ventricle, which, in a sagittal section through the cavity, appears as a pointed angle.

The Internal Structure of the Cerebellum

The cerebellum consists of white and grey substance.

White substance.—If a sagittal section (fig. 816) be made through either hemisphere, the interior will be found to consist of a central stem of white substance, in the middle of which is a grey mass, the *dentate nucleus*. From this central white stem a series of plates diverge; these plates are covered with grey substance and form the laminæ. The main branches from the central stem divide and subdivide, and a characteristic appearance, named the *arbor vitæ*, is presented. If the sagittal section be made through the middle of the vermis, it will be seen that the central stem divides into a vertical and a horizontal branch. The *vertical* branch passes upwards to the culmen monticuli, where it subdivides freely, one of its ramifications passing forwards and upwards to the central lobule. The *horizontal* branch passes backwards to the folium vermis, greatly diminished in size in consequence of having given off large secondary branches: one of the latter ascends to the clivus monticuli; the others descend, and enter the tuber vermis, the pyramid, the uvula, and the nodule.

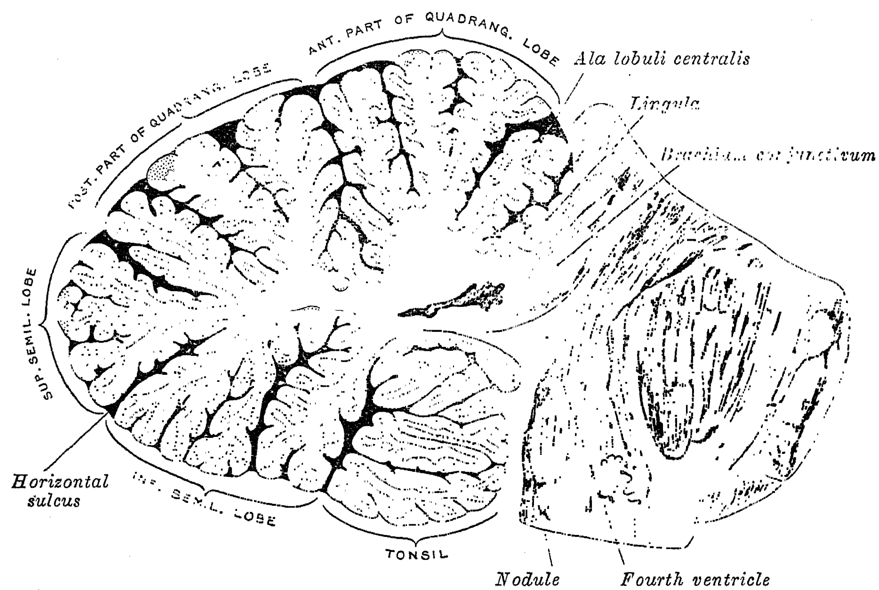
The white substance of the cerebellum consists of *projection fibres* and *fibræ propriæ*.

Projection fibres.—The cerebellum is connected to the other parts of the brain by three large bundles of projection fibres, viz. to the cerebrum by the brachia conjunctiva, to the pons by the brachia pontis, and to the medulla oblongata by the restiform bodies (fig. 817).

The **brachia conjunctiva** (superior cerebellar peduncles) are two in number, one on either side; they emerge from the upper and medial part of the white substance of the hemispheres and are placed under cover of the upper part of the cerebellum. They are joined to each other across the middle line by the anterior medullary velum, and can be followed upwards as far as the inferior colliculi, under which they disappear. Below, they form the upper lateral boundaries of the fourth ventricle, but as they ascend they converge on the dorsal aspect of the ventricle and form a part of its roof.

Most of the fibres of the brachium conjunctivum are derived from the cells of the dentate nucleus of the cerebellum (p. 821), and emerge from the hilum of

FIG. 816.—A sagittal section through the left cerebellar hemisphere, near its junction with the vermis. (Sharpey Schafer.)



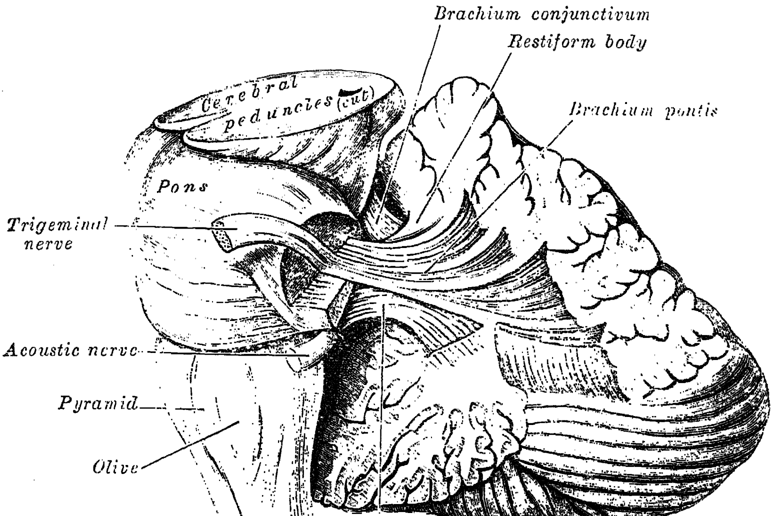
this nucleus, but a few arise from the cells of the smaller grey nuclei in this cerebellar white substance. The fibres of the two brachia are continued upwards beneath the corpora quadrigemina, and on the ventral surface of the cerebral aqueduct they undergo a complete decussation, and then divide into ascending and descending branches; most of the ascending branches end in the red nucleus, but some go to the thalamus and the nucleus of the oculomotor nerve; the descending branches can be traced into the pons and medulla oblongata; Cajal believes them to be continued into the anterior and lateral funiculi of the medulla spinalis. The fibres of the anterior spinocerebellar fasciculus pass through the brachia conjunctiva to reach the cerebellum. Tectocerebellar fibres pass from the roof of the midbrain to the cerebellum through the brachia conjunctiva.

The **brachia pontis** (middle cerebellar peduncles) (fig. 817) are largely composed of centripetal fibres, which arise from the cells of the nuclei pontis of the opposite side and end in the cerebellar cortex; they are said to contain also some efferent fibres to the nuclei pontis, and others to the medulla spinalis. The fibres of each brachium pontis are arranged in three fasciculi, superior, inferior, and deep. The *superior* fasciculus is derived from the upper transverse fibres of the pons; it is directed backwards and lateralwards superficial to the other two fasciculi, and is distributed mainly to the lobules on the inferior

surface of the cerebellar hemisphere, and to the parts of the superior surface adjoining the posterior and lateral margins. The *inferior* fasciculus is formed by the lowest transverse fibres of the pons; it passes under cover of the superior fasciculus and is continued downwards and backwards more or less parallel with it, to be distributed to the folia on the under surface close to the vermis. The *deep* fasciculus comprises most of the deep transverse fibres of the pons. It is at first covered by the superior and inferior fasciculi, but crossing obliquely it appears on the medial side of the superior, from which it receives a bundle; its fibres spread out and pass to the upper anterior cerebellar folia. The fibres of this fasciculus cover those of the restiform body.*

The **restiform bodies** (inferior cerebellar peduncles) pass at first upwards and lateralwards, forming parts of the lateral walls of the fourth ventricle, and then bend abruptly backwards to enter the cerebellum between the brachia conjunctiva and brachia pontis. Each restiform body contains the following

Fig. 817.—A dissection showing the projection fibres of the cerebellum. (E. B. Jamieson.)



fasciculi: (1) the direct cerebellar tract (posterior spinocerebellar fasciculus) of the medulla spinalis, which ends mainly in the cortex of the superior vermis; (2) fibres from the nucleus gracilis and nucleus cuneatus, of the same and of the opposite side; (3) fibres from the opposite inferior olivary nucleus; (4) crossed and uncrossed fibres from the reticular formation of the medulla oblongata; (5) vestibular fibres, derived partly from the vestibular division of the acoustic nerve and partly from the nuclei in which this division ends—these fibres occupy the medial segment of the restiform body and divide into ascending and descending branches; the ascending branches partly end in the opposite roof nucleus and partly in the cortex of the cerebellum; (6) cerebellobulbar fibres which come from the opposite roof nucleus and probably from the dentate nucleus, and end in the nucleus of Deiters and in the formatio reticularis of the medulla oblongata.

The **fibræ propriæ** of the cerebellum are of two kinds: (1) *commissural fibres*, which cross the middle line at the anterior and posterior parts of the vermis and connect the opposite halves of the cerebellum; (2) *arcuate or association fibres*, which connect adjacent lobules and laminæ with each other.

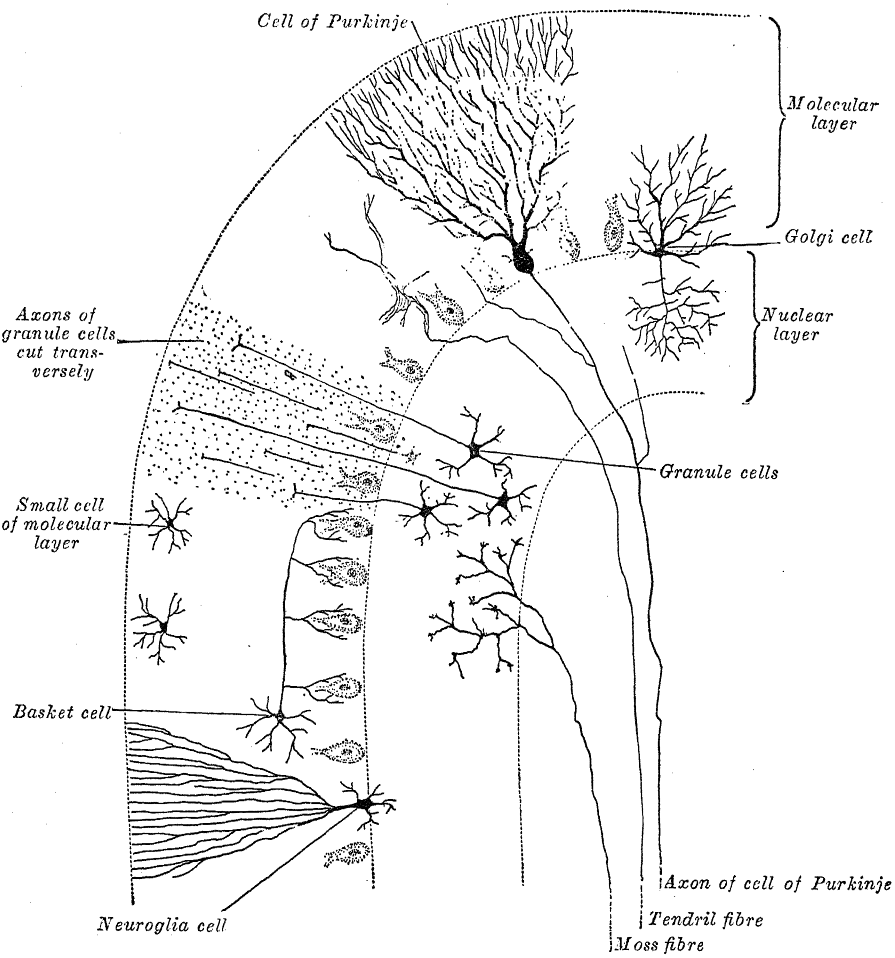
Grey substance.—The grey substance of the cerebellum is found in two situations: (1) on the surface, forming the cortex; (2) as independent masses in the interior.

* Consult an article by E. B. Jamieson, *Journal of Anatomy and Physiology*, vol. xliv.

(1) The **grey substance of the cortex** presents a characteristic foliated appearance, due to the series of laminæ which project from the central white substance; these in their turn give off secondary laminæ, which are covered by grey substance. Externally the cortex is covered by pia mater; internally it rests on the white substance.

Microscopic appearance of the cortex (fig. 818).—The cortex consists of two layers, viz. an external grey, or molecular, layer, and an internal rust-coloured, or nuclear, layer; between these is an incomplete stratum of cells, the *cells of Purkinje.*

Fig. 818.—A transverse section through a cerebellar folium. Diagrammatic. (After Ramón y Cajal and Kölliker.)



The *external grey, or molecular, layer* consists of nerve-fibres and cells. The fibres comprise: (*a*) the dendrites and axon-collaterals of Purkinje's cells; (*b*) fibres from cells in the nuclear layer; (*c*) fibres from the central white substance of the cerebellum; (*d*) fibres derived from cells in the molecular layer itself. In addition to these are other fibres, which have a vertical direction and are the processes of large neuroglia-cells situated in the nuclear layer. They pass outwards to the periphery of the grey substance, where they expand into little conical enlargements which form a sort of limiting membrane beneath the pia mater, analogous to the membrana limitans interna of the retina.

The *cells of the molecular layer* are small, and are arranged in an inner and an outer layer; they all possess branched axons. The cells of the inner layer

are termed *basket-cells*; their axons run for some distance parallel with the surface of the folium and give off collaterals which form basket-like networks around the bodies of Purkinje's cells.

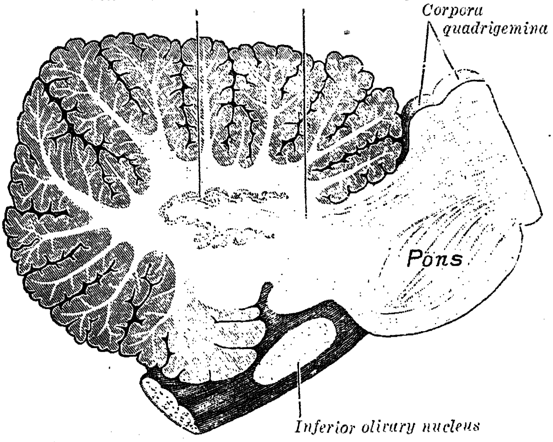
The *cells of Purkinje* are peculiar to the cerebellum; they form a single stratum of large, flask-shaped cells at the junction of the molecular and nuclear layers, their bases resting against the latter. The cells are flattened in a direction transverse to the long axis of a folium, and thus appear broad in sections carried across a folium, and fusiform in sections parallel to the long axis of a folium. From the neck of the flask one or more dendrites arise and pass into the molecular layer, where they subdivide and form an extremely rich arborescence, the various subdivisions of the dendrites being covered by lateral spine-like processes. This arborescence, like the cell, is flattened at right angles to the long axis of a folium; in other words, it resembles the branches of a fruit-tree trained against a trellis or a wall. Hence, in sections carried across a folium the arborescence is broad and expanded; whereas in sections parallel to the long axis of a folium, the arborescence, like the cell, is seen in profile, and is limited to a narrow area.

From the bottom of the flask-shaped cell the axon arises; this passes through the nuclear layer, and, becoming medullated, is continued as a nerve-fibre in the subjacent white substance. As it traverses the nuclear layer it gives off fine collaterals, some of which run into the molecular layer.

The *internal rust-coloured, or nuclear, layer* (fig. 818) contains numerous small nerve-cells of a reddish-brown colour, together with many nerve-fibrils. Most of the cells are nearly spherical and provided with short dendrites which spread out in a spider-like manner in the nuclear layer. Their axons pass into the molecular layer, and, bifurcating at right angles, run for some distance parallel to the long axis of the folium. In the outer part of the nuclear layer are some larger cells, of the type II. of Golgi. Their axons undergo frequent division as soon as they leave the nerve-cells, and pass into the nuclear layer; while their dendrites ramify chiefly in the molecular layer.

Finally, in the grey substance of the cerebellar cortex, there are fibres which come from the white centre and penetrate the cortex. The cell-origin of these fibres is unknown, but they are presumably afferent fibres, contained in the brachia and restiform bodies. Some of them end in the nuclear layer by dividing into numerous branches, on which are to be seen peculiar moss-like appendages; hence they have been termed by Ramón y Cajal the *moss-fibres*; they form an arborescence around the cells of the nuclear layer. Other fibres, the *clinging or tendril fibres*, can be traced into the molecular layer, where their branches cling around the dendrites of Purkinje's cells.

FIG. 819.—A sagittal section through the right cerebellar hemisphere. The right olive has also been cut sagittally.



(2) The **independent centres of grey substance** are imbedded in the white substance of the cerebellum, and are four in number on either side: one is of large size, and is known as the nucleus dentatus; the other three, much smaller, are situated near the middle of the cerebellum, and are known as the nucleus emboliformis, nucleus globosus, and nucleus fastigii.

The *nucleus dentatus* (fig. 819) is situated a little to the medial side of the centre of the stem of the white substance of the hemisphere. It consists of an irregularly folded grey lamina, containing a white centre, and presenting on its anteromedial aspect

(*d*) The *olivospinal fasciculus* (Helweg) arises in the vicinity of the inferior olivary nucleus in the medulla oblongata and is seen only in the cervical region of the medulla spinalis, where it forms a small triangular area at the periphery, close to the most lateral of the anterior nerve-roots. Its exact origin and its mode of ending have not been definitely made out.

2. **Ascending fasciculi.**—(*a*) The *direct cerebellar tract of Flechsig* (posterior spinocerebellar fasciculus) is situated at the periphery of the posterior portion of the lateral funiculus, and on transverse section appears as a flattened band reaching as far forwards as a line drawn transversely through the central canal of the medulla spinalis. Medially it is in contact with the lateral cerebrospinal fasciculus; behind, with the fasciculus of Lissauer. It begins about the level of the second or third lumbar nerve, increases in size as it ascends, and finally passes to the cerebellum through the restiform body. Its fibres are the axons of the cells of the dorsal nucleus (Clarke's column) of the same side; they receive their medullary sheaths about the sixth or seventh month of fœtal life.

(*b*) The *superficial anterolateral fasciculus* (tract of Gowers) skirts the periphery of the lateral funiculus in front of the direct cerebellar tract. In transverse section it is shaped somewhat like a comma, the expanded end lying in front of the lateral cerebrospinal fasciculus while the tail reaches forwards into the anterior funiculus. Its fibres are derived from the cells of the dorsal nucleus and from other cells of the posterior column. The superficial anterolateral fasciculus begins about the level of the third pair of lumbar nerves, and, increasing in size as it ascends, can be followed into the medulla oblongata and pons. It consists of three fasciculi: (1) the *anterior spinocerebellar*, partly crossed and partly uncrossed, passes to the cerebellum by way of the brachia conjunctiva; (2) the *lateral spinothalamic* ends in the thalamus; and (3) the *spinotectal* passes to the corpora quadrigemina.

(*c*) The *fasciculus of Lissauer* is a small strand situated at the tip of the posterior grey column, close to the entrance of the posterior nerve-roots. It consists of fine fibres which do not receive their medullary sheaths until near the close of fœtal life; some of its fibres are said to remain non-medullated throughout life. It is usually regarded as being formed by some of the lateral fibres of the posterior nerve-roots, which ascend for a short distance in the tract and then enter the posterior grey column, but its fibres are myelinated later than those of the posterior nerve-roots, and do not undergo degeneration in locomotor ataxia; they are probably intersegmental in character.

(*d*) The *fasciculus proprius lateralis* (lateral basis bundle) constitutes the remainder of the lateral funiculus, and is continuous in front with the anterior proper fasciculus. It consists chiefly of intersegmental fibres which arise from cells in the grey substance, and, after a longer or shorter course, re-enter the grey substance and ramify in it. Most of the intersegmental fibres of the anterior and lateral proper fasciculi are confined to the same side, but some cross to the opposite side, of the medulla spinalis. Some of the fibres of the lateral proper fasciculus are continued upwards into the brain under the name of the medial longitudinal fasciculus.

Fasciculi in the posterior funiculus.—This funiculus comprises two main fasciculi, viz. the fasciculus gracilis and the fasciculus cuneatus. These are separated from each other in the cervical and upper thoracic regions by the postero-intermediate septum (p. 787), and consist mainly of ascending fibres derived from the posterior nerve-roots.

The *fasciculus gracilis* (tract of Goll) lies next the posterior median septum, and is wedge-shaped on transverse section, its base being at the surface of the medulla spinalis. It increases in size from below upwards (fig. 793), and consists of long thin fibres which are derived from the posterior nerve-roots, and ascend as far as the medulla oblongata, where they end in the nucleus gracilis.

The *fasciculus cuneatus* (tract of Burdach) is triangular on transverse section, and lies between the fasciculus gracilis and the posterior grey column, with its base on the surface of the medulla spinalis. Its fibres, larger than those of the fasciculus gracilis, are mostly derived from the same source, viz. the posterior nerve-roots. Some of its fibres ascend for only a short distance, and, entering the grey substance, come into relationship with the cells of the dorsal nucleus; others can be traced as far as the medulla oblongata, where they end in the nucleus gracilis and nucleus cuneatus.

Lateral boundaries.—The lower part of each lateral boundary is constituted by the clava, the fasciculus cuneatus, and the restiform body; the upper part by the brachium pontis and the brachium conjunctivum.

The **roof** or **dorsal wall** (fig. 820).—The upper portion of the roof is formed by the brachia conjunctiva and the anterior medullary velum; the lower portion, by the posterior medullary velum, the epithelial lining of the ventricle covered by the tela chorioidea inferior, the tæniæ of the ventricle, and the obex.

The *brachia conjunctiva* (p. 818), on emerging from the central white substance of the cerebellum, pass upwards and forwards, forming at first the lateral boundaries of the upper part of the ventricle; on approaching the inferior colliculi, they converge, and their medial portions overlap the ventricle and form part of its roof.

The *anterior medullary velum* (p. 817) fills the angular interval between the brachia conjunctiva, and is continuous behind with the central white substance of the cerebellum; it is covered on its dorsal surface by the lingula of the superior vermis.

The *posterior medullary velum* (p. 817) is continued downwards and forwards from the central white substance of the cerebellum in front of the nodule and tonsillæ, and ends inferiorly in a thin, concave, somewhat ragged margin. Below this margin the roof of the ventricle is devoid of nervous matter except in the immediate vicinity of the lower lateral boundaries of the ventricle, where two narrow white bands, the *tæniæ of the fourth ventricle,* appear; these bands meet over the inferior angle of the ventricle in a thin triangular lamina, the *obex.* The non-nervous part of the roof is formed by the *epithelial lining of the ventricle,* which is prolonged downwards as a thin membrane, from the deep surface of the posterior medullary velum to the corresponding surface of the obex and tæniæ, and thence on to the floor of the ventricular cavity; it is covered and strengthened by a portion of the pia mater which is named the *tela chorioidea of the fourth ventricle.*

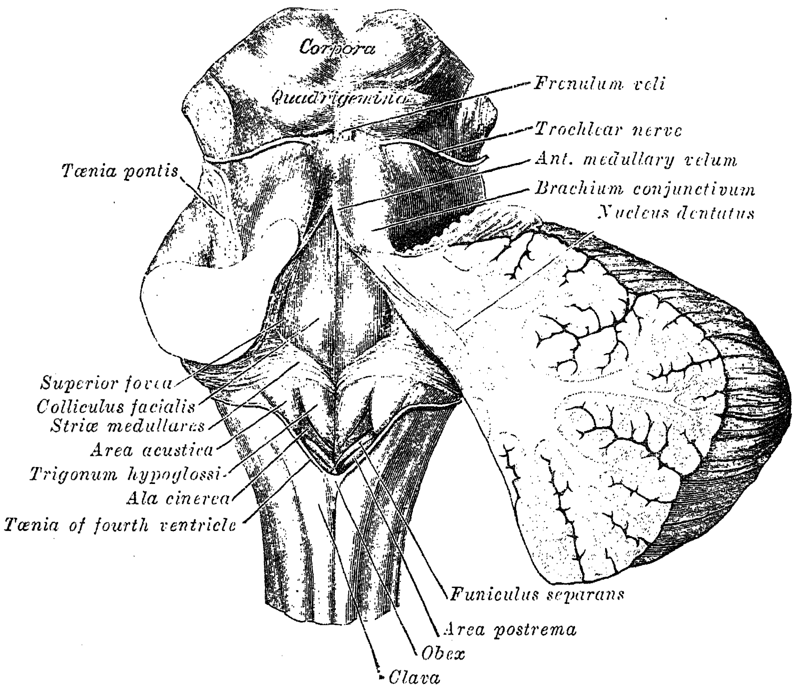
The *tæniæ of the fourth ventricle* (ligulæ) (fig. 821) are two narrow bands of white matter, one on either side, which complete the lower part of the roof of the ventricle. Each consists of a vertical and a horizontal part. The vertical part is continuous with the clava, to which it is adherent by its lateral border. The horizontal portion extends transversely across the restiform body, below the striæ medullares, and forms the roof of the lower and posterior part of the lateral recess; it is attached by its lower margin to the restiform body, and partly encloses the chorioid plexus, which, however, projects beyond it like a cluster of grapes. The *obex* is a thin, triangular, grey lamina, which covers the lower angle of the ventricle and is attached by its lateral margins to the clavæ. The *tela chorioidea of the fourth ventricle* is the name applied to the triangular fold of pia mater which is carried upwards between the cerebellum and the medulla oblongata. It consists of two layers, which are continuous with each other in front, and are more or less adherent throughout. The posterior layer covers the antero-inferior surface of the cerebellum, while the anterior is applied to the structures which form the lower part of the roof of the ventricle, and is continuous inferiorly with the pia mater on the restiform bodies and the closed part of the medulla.

The **openings in the roof.**—In the roof of the fourth ventricle there are three openings, a median and two lateral: the median aperture (*foramen Majendii*) is situated immediately above the inferior angle of the ventricle; the lateral apertures are found at the ends of the lateral recesses. Through these openings the ventricular cavity communicates with the subarachnoid cavity, and the cerebrospinal fluid can circulate from the one cavity to the other.

The **chorioid plexuses.**—Two highly vascular fringe-like processes of the tela chorioidea are named the chorioid plexuses of the fourth ventricle; they invaginate the lower part of the roof of the ventricle and are everywhere covered by the epithelial lining of the cavity. Each consists of a vertical and a horizontal portion: the former lies close to the middle line, and the latter passes into the lateral recess and projects through the lateral aperture. The vertical parts of the plexuses are distinct from each other, but the horizontal portions are joined in the middle line; and hence the entire structure presents the form of the letter T, the vertical limb of which, however, is double.

The **rhomboid fossa** (fig. 821).—The anterior wall or floor of the fourth ventricle is named, from its shape, the rhomboid fossa; it is formed by the posterior surfaces of the pons and medulla oblongata. It is covered by a layer of grey substance continuous with that of the medulla spinalis; superficial to this is a thin lamina of neuroglia which constitutes the ependyma of the ventricle and supports a layer of ciliated epithelium. The fossa consists of three parts, superior, intermediate, and inferior. The *superior* part is triangular in shape and limited laterally by the brachia conjunctiva cerebelli; its apex, directed upwards, is continuous with the cerebral aqueduct; its base is represented by an imaginary line at the level of the upper ends of two small depressions, named the superior foveæ. The *intermediate* part extends from this level to that of the horizontal portions of the tæniæ of the ventricle and

FIG. 821.—The rhomboid fossa.



is prolonged into the lateral recesses. The *inferior* part is triangular, and its downwardly directed apex, named the *calamus scriptorius*, is continuous with the wall of the central canal of the closed part of the medulla oblongata.

The rhomboid fossa is divided into symmetrical halves by a *median sulcus* which reaches from the upper to the lower angle of the fossa and is deeper below than above. On either side of this sulcus is an elevation, the *medial eminence*, bounded laterally by a sulcus, the *sulcus limitans*. In the superior part of the fossa the medial eminence has a width equal to that of the corresponding half of the fossa, but opposite the superior fovea it forms an elongated swelling, the *colliculus facialis*, which overlies the nucleus of the abducent nerve, and is in part produced by the ascending portion of the root of the facial nerve. In the inferior part of the fossa the medial eminence assumes the form of a triangular area, the *trigonum hypoglossi*. When examined under water with a lens the trigonum hypoglossi is seen to consist of a medial and a lateral area separated by a series of oblique furrows; the medial area corresponds with the upper part of the nucleus of the hypoglossal nerve, the lateral with a small nucleus, the *nucleus intercalatus*.

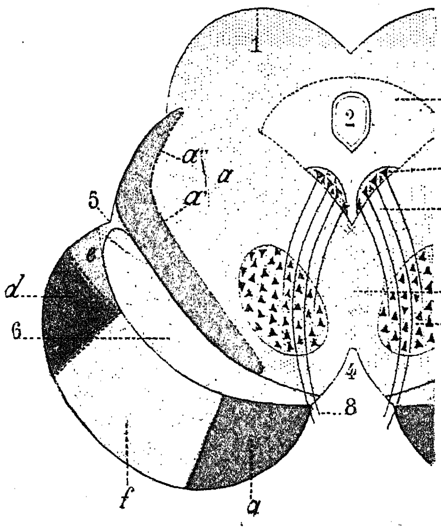
The *sulcus limitans* forms the lateral boundary of the medial eminence. Its superior part corresponds with the lateral limit of the fossa and presents a bluish-grey area, the *locus cæruleus*, which owes its colour to a patch of deeply

pigmented nerve-cells, termed the *substantia ferruginea.* At the level of the colliculus facialis the sulcus limitans widens into a flattened depression, the *superior fovea,* and in the inferior part of the fossa appears as a distinct dimple, the *inferior fovea.* Lateral to the foveæ is a rounded elevation named the *area acustica,* which extends into the lateral recess. Winding round the restiform body and crossing the area acustica and the medial eminence are a number of white strands, the *striæ medullares* (striæ acusticæ), which form a portion of the cochlear division of the acoustic nerve and disappear into the median sulcus. Below the inferior fovea, and between the trigonum hypoglossi and the lower part of the area acustica, is a triangular dark field, the *ala cinerea,* in which the sensory fibres of the vagus and glossopharyngeal nerves end. The lower part of the ala cinerea is crossed by a narrow translucent ridge, the *funiculus separans,* and between this funiculus and the clava is a small tongue-shaped area, the *area postrema.* On section it is seen that the funiculus separans is formed by a strip of thickened ependyma, and the area postrema by loose, highly vascular, neuroglial tissue containing nerve-cells of moderate size.

THE MESENCEPHALON OR MID-BRAIN

The **mesencephalon** or **mid-brain** is the short, constricted portion which connects the pons and cerebellum with the thalamencephalon and cerebral hemispheres. It is directed upwards and forwards, and consists of (1) a ventrolateral portion, composed of a pair of cylindrical bodies, named the *cerebral peduncles*; (2) a dorsal portion, consisting of four rounded eminences, named the *corpora quadrigemina*; and (3) an intervening passage or tunnel, the *cerebral aqueduct,* which represents the original cavity of the mid-brain, and connects the third and fourth ventricles (fig. 822).

FIG. 822.—A transverse section through the mid-brain. Schematic. (Testut.)



1. Corpora quadrigemina. 2. Cerebral aqueduct. 3. Central grey stratum. 4. Interpeduncular space. 5. Sulcus lateralis. 6. Substantia nigra. 7. Red nucleus of tegmentum. 8. Oculomotor nerve, with 8'. its nucleus of origin. *a*. Lemniscus (in blue), with *a'* the medial lemniscus and *a''* the lateral lemniscus. *b*. Medial longitudinal fasciculus. *c*. Raphe. *d*. Temporopontine fibres. *e*. Portion of medial lemniscus which runs to the lentiform nucleus and insula. *f*. Cerebrospinal fibres. *g*. Frontopontine fibres.

The **cerebral peduncles** (crura cerebri) (fig. 798) are two cylindrical masses situated at the base of the brain, and largely hidden by the temporal lobes of the cerebrum, which must be drawn aside or removed in order to expose them. They emerge from the upper surface of the pons, one on either side of the middle line, and, diverging as they pass upwards and forwards, disappear into the substance of the cerebral hemispheres. Curving round each peduncle, close to the upper surface of the pons, a thin white band, the *tænia pontis,* is frequently seen; it enters the cerebellum between the brachium pontis and brachium conjunctivum. The depressed area between the diverging cerebral peduncles is termed the *interpeduncular fossa,* and consists of a layer of greyish substance, the *posterior perforated substance,* which is pierced by small apertures for the transmission of blood-vessels. The lower part of the posterior perforated substance lies on the ventral aspect of the tegmenta, and contains a nucleus named the *interpeduncular ganglion* (p. 827); its upper part assists in forming the floor of the third ventricle.

The ventral surface of each peduncle is crossed behind, from the medial to the lateral side, by the superior cerebellar and posterior cerebral arteries, while, close to the point of disappearance of the peduncle into the cerebral hemisphere, the optic tract winds forwards around it. The medial surface of the peduncle forms the lateral boundary of the interpeduncular fossa, and is marked by a

Fig. 823.—A transverse section through the mid-brain at the level of the inferior colliculi.

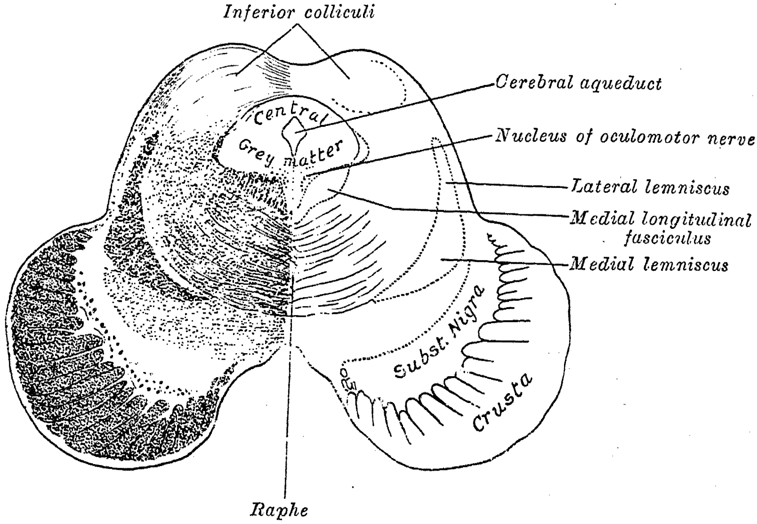
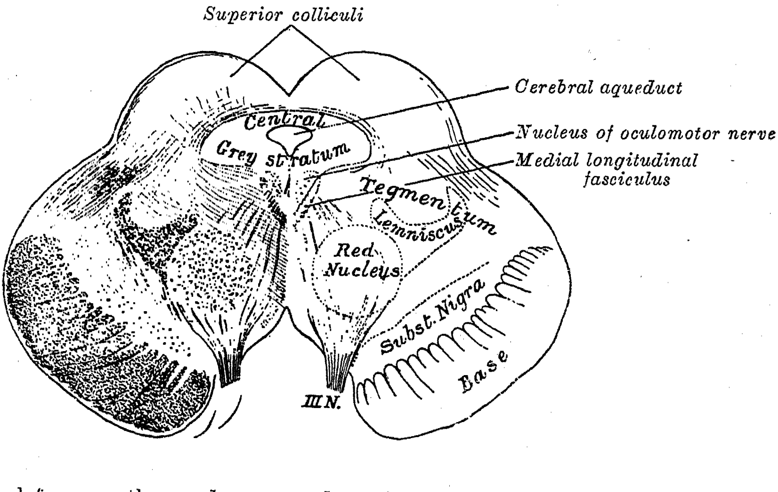


Fig. 824.—A transverse section through the mid-brain at the level of the superior colliculi.



longitudinal furrow, the *oculomotor sulcus*, from which the roots of the oculomotor nerve emerge (fig. 824). The lateral surface of the peduncle is in relation with the gyrus hippocampi of the cerebral hemisphere and is crossed from behind forwards by the trochlear nerve (fig. 789). Running along this surface is a longitudinal furrow, termed the *lateral sulcus*; the fibres of the lateral lemniscus come to the surface in this sulcus, and pass backwards and upwards, to disappear under the inferior colliculus.

Structure of the cerebral peduncles (figs. 823, 824).—On transverse section, each peduncle is seen to consist of a dorsal and a ventral part, separated by a deeply pigmented lamina of grey substance, termed the *substantia nigra.*

The dorsal part is named the *tegmentum*; the ventral, the *base* or *crusta*. The bases of the peduncles are separated from each other, but the tegmenta are joined in the median plane by a forward prolongation of the raphe of the pons. Laterally, the tegmenta are free; dorsally, they blend with the corpora quadrigemina.

The **base** (crusta or pes) is semilunar on transverse section, and consists almost entirely of longitudinal bundles of efferent fibres which arise from the cells of the cerebral cortex and are grouped into three principal sets, viz. cerebrospinal, frontopontine, and temporopontine (fig. 822). The *cerebrospinal* fibres are derived from the cells of the motor area of the cerebral cortex and occupy the middle three-fifths of the base; some of them end in the nuclei of the motor cerebral nerves of the opposite side, but most of them pass into the pyramids of the medulla oblongata. The *frontopontine* fibres are situated in the medial fifth of the base; they arise from the cells of the frontal lobe and end in the nuclei of the pons. The *temporopontine* fibres are lateral to the cerebrospinal fibres; they originate in the temporal lobe and end in the nuclei of the pons.*

The **substantia nigra** is a layer of grey substance containing numerous deeply pigmented, multipolar nerve-cells. It is semilunar on transverse section, its concavity being directed towards the tegmentum; from its convex surface, processes extend between the fibres of the base of the peduncle. Thicker medially than laterally, it reaches from the oculomotor sulcus to the lateral sulcus, and extends from the upper surface of the pons to the subthalamic region; its medial part is traversed by the fibres of the oculomotor nerve as these stream forwards to reach the oculomotor sulcus. The substantia nigra receives afferent fibres from the corpus striatum of the same, and of the opposite side, and sends efferent fibres to the reticular formation of the tegmentum.

The **tegmentum** is continuous below with the reticular formation of the pons, and, like the latter, consists of a considerable amount of grey substance together with longitudinal and transverse fibres. The principal grey masses of the tegmentum are the red nucleus and the interpeduncular ganglion; of its fibres the chief longitudinal tracts are the brachium conjunctivum, the medial longitudinal fasciculus, and the lemniscus.

Grey substance.—The *red nucleus* is situated in the anterior part of the tegmentum, and is continued upwards into the posterior part of the subthalamic region. In sections at the level of the superior colliculus it appears as a circular mass which is traversed by the fibres of the oculomotor nerve. Most of the ascending branches of the opposite brachium conjunctivum (p. 818) end in this nucleus; it also receives fibres from the corpus striatum and the frontal lobe. The axons of some of its cells cross the middle line and are continued downwards into the lateral funiculus of the medulla spinalis as the rubrospinal tract (p. 794); those of other cells end in the thalamus, the nucleus of the lateral lemniscus, and in the reticular formation of the medulla oblongata.

The *interpeduncular ganglion* is a median collection of nerve-cells situated in the ventral part of the tegmentum. The fibres of the fasciculus retroflexus of Meynert, which have their origin in the cells of the ganglion habenulæ (p. 836), end in the interpeduncular ganglion.

Besides the two nuclei mentioned, there are small collections of nerve-cells which form the dorsal and ventral nuclei and the central nucleus or nucleus of the raphe.

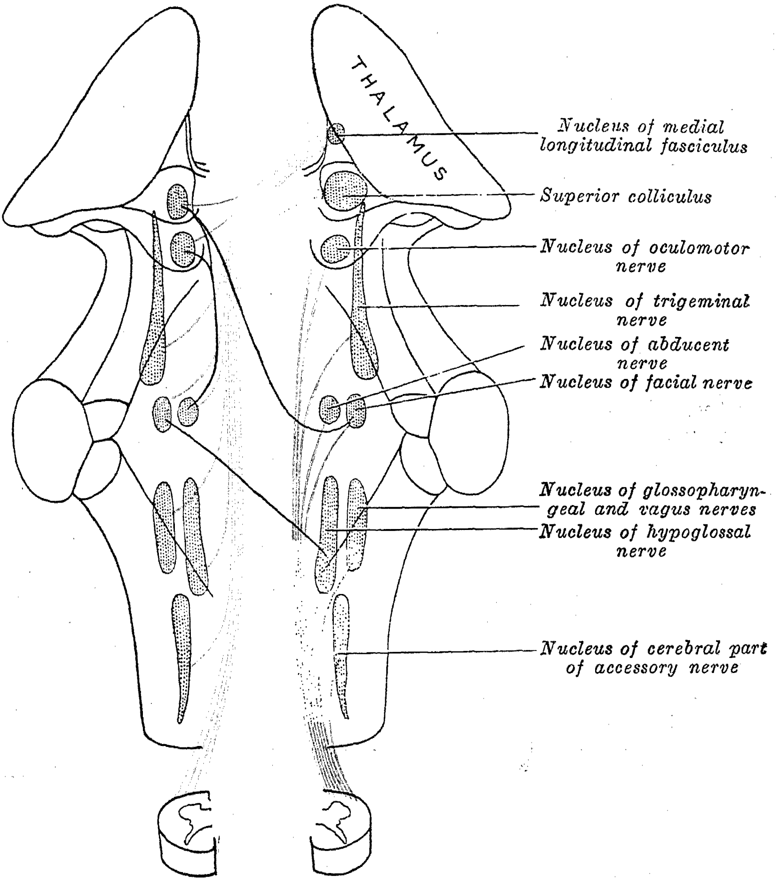
White substance.—(1) The origin and course of the *brachium conjunctivum* have already been described (p. 818).

(2) The *medial (posterior) longitudinal fasciculus* (fig. 825) is continuous below with the fasciculi proprii of the anterior and lateral funiculi of the medulla spinalis; and has been traced by Edinger as far as a nucleus, the *nucleus of the medial longitudinal fasciculus*, situated in the hypothalamus, immediately in front of the cerebral aqueduct. In the medulla oblongata and pons, it runs close to the middle line, near the floor of the fourth ventricle; in the mesen-

* A band of fibres, the *tractus peduncularis transversus*, is sometimes seen emerging from in front of the superior colliculus; it passes round the ventral surface of the peduncle about midway between the pons and the optic tract, and dips into the oculomotor sulcus. This band is a constant structure in many mammals, but is only present in about thirty per cent. of human brains. Since it undergoes atrophy after enucleation of the eyeballs, it may be considered as forming a path for visual sensations.

cephalon, it is situated on the ventral aspect of the cerebral aqueduct, below the nuclei of the oculomotor and trochlear nerves. Its connexions are imperfectly known, but it consists largely of ascending and descending intersegmental or association fibres, which connect the nuclei of the rhombencephalon and mesencephalon to each other. It forms an important link between the nuclei of the oculomotor, trochlear, and abducent nerves, and conveys fibres from the nucleus of the abducent nerve into the trochlear nerve of the opposite side and through this nerve to the Rectus medialis oculi. Many fibres enter it from the lateral nucleus (Deiters' nucleus) of the vestibular nerve, and divide into

Fig. 825.—A scheme of the medial longitudinal fasciculus; motor fibres in red, sensory fibres in blue.



ascending and descending branches; the former ending in the nuclei of the oculomotor, trochlear, and abducent nerves, the latter passing into the anterior funiculus of the spinal medulla. Fibres arise in the superior colliculus and in the nucleus of the medial longitudinal fasciculus and, after decussating in the middle line, end in the motor nuclei of the pons and medulla oblongata. Other fibres ascend from the grey matter of the spinal medulla and from the nuclei in the medulla oblongata to the nuclei in the pons and mid-brain. Fibres are said to be prolonged through this fasciculus from the nucleus of the oculomotor nerve into the facial nerve, and through the latter nerve to the Orbicularis oculi, the Corrugator, and the Frontalis.*

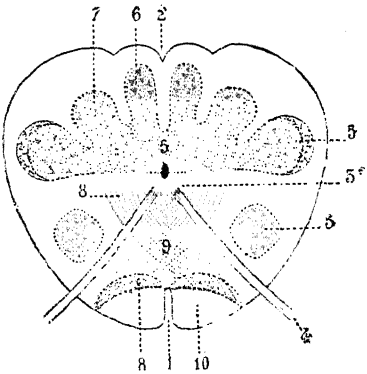
The fibres of the *lemniscus* or *fillet* (fig. 827) take origin in the nucleus gracilis and nucleus cuneatus of the medulla oblongata, and cross to the opposite side

* Bruce and Pirie ('On the Origin of the Facial Nerve,' *Review of Neurology and Psychiatry*, vol. vi. No. 12, December 1908) produce weighty evidence against the view that the facial nerve derives fibres from the nucleus of the oculomotor nerve.

in the sensory decussation (p. 805). They then pass upwards through the medulla oblongata, in which they are situated behind the cerebrospinal fibres. Here they are joined by the fibres of the spinothalamic fasciculi, these having already undergone decussation in the medulla spinalis. As the lemniscus ascends, it receives additional fibres from the terminal nuclei of the sensory cerebral nerves of the opposite side. In the pons, it assumes a flattened, ribbon-like appearance, and is placed dorsal to the trapezium. In the mesencephalon, its lateral part is folded backwards and forms nearly a right angle with its medial portion; and hence it is customary to speak of a lateral and a medial lemniscus.

The *lateral lemniscus* comes to the surface in the lateral sulcus of the mid-brain, and disappears under the inferior colliculus. It consists of fibres from the terminal nuclei of the cochlear division of the acoustic nerve, together with others from the superior olivary and trapezoid nuclei. Most of the fibres of the lateral lemniscus end in the inferior colliculus but some reach the medial geniculate body through the inferior quadrigeminal brachium.

Fig. 826.—A transverse section through the sensory decussation (decussation of the lemniscus). Schematic. (Testut.)



1. Anterior median fissure. 2. Posterior median sulcus. 3, 3'. Head and base of the anterior column (in red). 4. Hypoglossal nerve. 5. Bases of the posterior columns. 5'. Tuberculum cinereum (tubercle of Rolando). 6. Nucleus gracilis. 7. Nucleus cuneatus. 8, 8. Lemniscus. 9. Sensory decussation. 10. Pyramid.

The *medial lemniscus* begins in the nucleus gracilis and nucleus cuneatus of the opposite side, and is joined by the spinothalamic fasciculi of the medulla spinalis, and by fibres from the terminal nuclei of the sensory cerebral nerves of the opposite side, excepting the cochlear division of the acoustic nerve. In the cerebral peduncle, a few of its fibres pass upwards in the lateral part of the base of the peduncle on the dorsal aspect of the temporopontine fibres, and reach the lentiform nucleus and the insula. With this exception the fibres of the medial lemniscus are prolonged through the tegmentum into the thalamus, around the cells of which they form arborisations. From the cells of the thalamus a relay of fibres is prolonged to the cerebral cortex.

The **corpora quadrigemina** (fig. 831) are four rounded eminences which form the dorsal part of the mesencephalon. They are situated above and in front of the anterior medullary velum and brachia conjunctiva, and below and behind the third ventricle and posterior commissure. They are covered by the splenium of the corpus callosum, and are partly overlapped on either side by the medial angle, or pulvinar, of the posterior end of the thalamus. The corpora quadrigemina are arranged in pairs (superior and inferior colliculi), and are separated from one another by a crucial sulcus. The longitudinal part of this sulcus expands superiorly to form a slight depression which supports the *pineal body*, a cone-like structure which projects backwards from the thalamencephalon and partly obscures the superior colliculi. From the inferior end of the longitudinal sulcus a white band, termed the *frenulum veli*, is prolonged downwards to the anterior medullary velum; on either side of this band the trochlear nerve emerges, and passes forwards on the lateral aspect of the cerebral peduncle to reach the base of the brain. The *superior colliculi* are larger and darker in colour than the inferior, and are oval in shape. The *inferior colliculi* are hemispherical, and somewhat more prominent than the superior. The superior colliculi are associated with the sense of sight, the inferior with that of hearing.

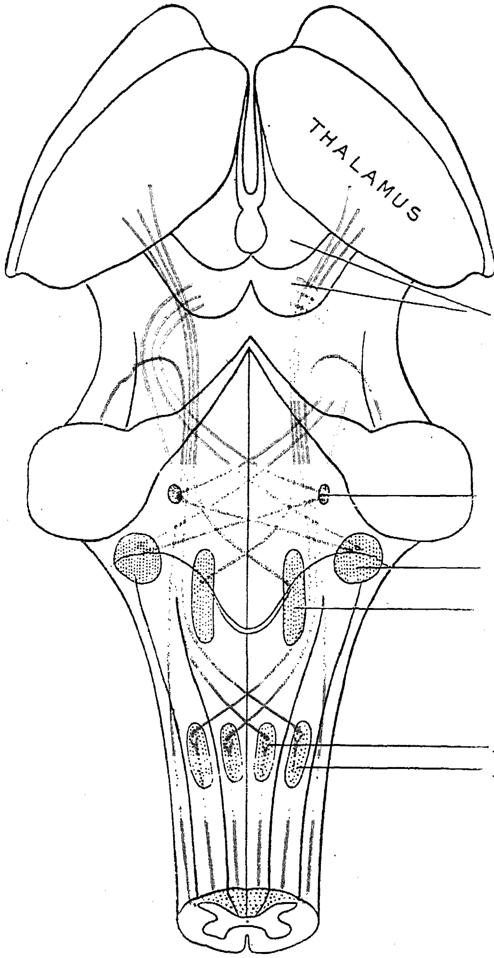
From the lateral aspect of each colliculus a white band, termed the *brachium*, is prolonged, upwards and forwards. The *superior brachium* extends lateralwards from the superior colliculus, and, passing between the pulvinar and medial geniculate body, is partly continued into an eminence called the lateral geniculate body, and partly into the optic tract. The *inferior brachium* passes

forwards and upwards from the inferior colliculus to which it conveys fibres from the lateral lemniscus to the medial geniculate body.

In close relationship with the corpora quadrigemina are the brachia conjunctiva, which emerge from the upper and medial parts of the cerebellar hemispheres. They run upwards and forwards, and, passing under the inferior colliculi, enter the tegmenta as already described (p. 818).

Structure of the corpora quadrigemina.—The *inferior colliculus* consists of a compact nucleus of grey substance which contains large and small

FIG. 827.—A scheme showing the course of the fibres of the lemniscus; medial lemniscus in blue, lateral in red.



multipolar nerve-cells, and is more or less completely surrounded by fibres derived from the lateral lemniscus; most of these fibres end in the grey nucleus of the same side, but some cross to that of the opposite side. From the cells of the grey nucleus, fibres are prolonged through the inferior brachium into the tegmentum of the cerebral peduncle, and are carried to the thalamus and the cortex of the temporal lobe; other fibres cross the middle line and end in the opposite colliculus.

The *superior colliculus* is covered by a thin stratum (*stratum zonale*) of white fibres, the majority of which are derived from the optic tract. Beneath this is the *stratum cinereum*, a cap-like layer of grey substance, thicker in the centre than at the circumference, and consisting of numerous small multipolar nerve-cells imbedded in a fine network of nerve-fibres. Still deeper is the *stratum opticum*, containing large multipolar nerve-cells separated by

numerous fine nerve-fibres. Finally, there is the *stratum lemnisci*, consisting of fibres derived partly from the lemniscus and partly from the cells of the stratum opticum; interspersed among these fibres are many large multipolar nerve-cells. Of the afferent fibres which reach the superior colliculus, the majority have their origins in the retina and are conveyed to the superior colliculus through the superior brachium; all of them end by arborising around the cells of the grey substance. Of the efferent fibres, a few cross the middle line to the opposite colliculus; many, after undergoing decussation (*fountain decussation of Meynert*), descend in the medial longitudinal fasciculus, some ending in the nuclei of the oculomotor, trochlear and abducent nerves, while others are continued downwards under the name of the tecto-spinal fasciculus through the formatio reticularis of the mesencephalon, pons and medulla oblongata into the medulla spinalis, where they are found in the anterior and lateral funiculi.

The corpora quadrigemina are relatively larger in the lower mammals than in man. In fishes, reptiles, and birds, there are only two, hollow, colliculi (corpora bigemina); they represent the superior colliculi of mammals, and are frequently termed the optic lobes, because of their intimate connexion with the optic tracts.

The **cerebral aqueduct** (aqueduct of Sylvius) is a narrow canal, about 15 mm. long, situated between the corpora quadrigemina and tegmenta, and connecting the third with the fourth ventricle. Its form, as seen in transverse sections, varies at different levels, being T-shaped below, triangular above, and oval in the middle; its central part is slightly dilated, and was named by Retzius the *ventricle of the mid-brain*. It is lined by ciliated columnar epithelium, and is surrounded by a layer of grey substance named the *central grey stratum*; this is continuous below with the grey substance in the rhomboid fossa, and above with that of the third ventricle. Dorsally, the aqueduct is partly separated from the grey substance of the quadrigeminal bodies by the fibres of the lemnisci; ventral to it are the medial longitudinal fasciculus, and the formatio reticularis of the tegmentum. Scattered throughout the central grey stratum are numerous nerve-cells of various sizes, interlaced by a network of fine fibres. Besides these scattered cells it contains three groups which constitute the nucleus of the mesencephalic root of the trigeminal nerve and the nuclei of the oculomotor and trochlear nerves. The *nucleus of the mesencephalic root of the trigeminal nerve* extends along the entire length of the aqueduct, and occupies the lateral part of the grey stratum, while the nuclei of the oculomotor and trochlear nerves are situated in its ventral part. The *nucleus of the oculomotor nerve* is about 10 mm. long, and lies mainly under the superior colliculus, beyond which, however, it extends for a short distance into the grey substance of the third ventricle. The *nucleus of the trochlear nerve* is small and nearly circular, and is on a level with a plane carried transversely through the upper part of the inferior colliculus.

THE PROSENCEPHALON OR FORE-BRAIN

The **prosencephalon** or **fore-brain** consists of: (1) the *diencephalon*, corresponding in a large measure to the third ventricle and the structures which bound it; and (2) the *telencephalon*, comprising the largest part of the brain, viz. the cerebral hemispheres; these hemispheres are connected with each other across the middle line, and each contains a large cavity, named the lateral ventricle. The lateral ventricles communicate through the inter-ventricular foramen with the third ventricle, but are separated from each other by a median septum, the septum pellucidum; this contains a slit-like cavity, which does not communicate with the ventricles.

The Diencephalon

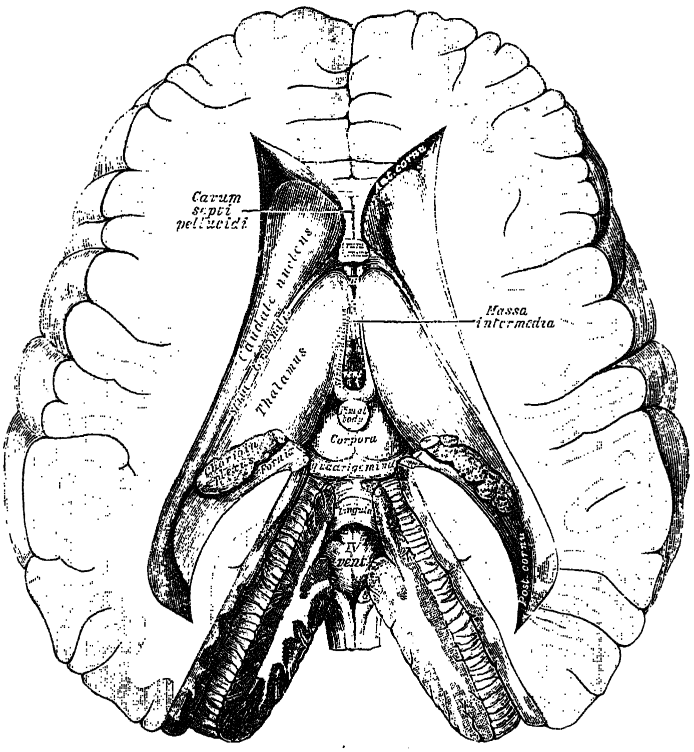
The **diencephalon** is connected above and in front with the cerebral hemispheres; behind with the mesencephalon. Its upper surface is concealed by the corpus callosum, and is covered by a fold of pia mater, named the

tela chorioidea of the third ventricle; inferiorly it reaches to the base of the brain. The diencephalon comprises: (1) the thalamencephalon; (2) the pars mamillaris hypothalami; and (3) the posterior part of the third ventricle.

For descriptive purposes, however, it is more convenient to consider the whole of the third ventricle and its boundaries together: this necessitates the inclusion, under this heading, of the pars optica hypothalami and the corresponding part of the third ventricle—structures which properly belong to the telencephalon.

The **thalamencephalon** comprises: (1) the thalamus; (2) the metathalamus or corpora geniculata; and (3) the epithalamus, consisting of the trigonum habenulæ, the pineal body, and the posterior commissure.

FIG. 828.—The ventricles of the brain. Exposed from above.



The **thalami** (figs. 828, 829) are two large ovoid masses, situated one on either side of the third ventricle and reaching for some distance behind that cavity. Each thalamus is about 4 cm. long, and has two ends and four surfaces.

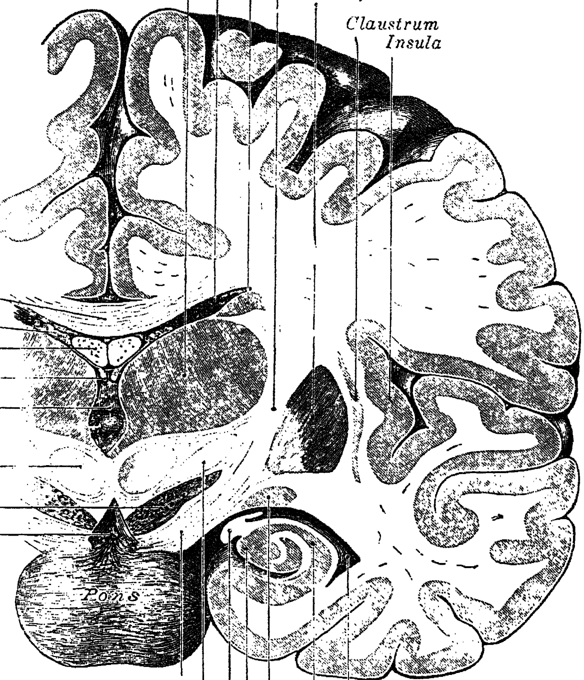
The *anterior end* is narrow; it lies close to the middle line and forms the posterior boundary of the interventricular foramen.

The *posterior end* is expanded, directed backwards and lateralwards, and overlaps the superior colliculus. Medially, this end presents an angular prominence, the *pulvinar*, which is continued laterally into an oval swelling, the *lateral geniculate body*, while beneath the pulvinar, but separated from it by the superior brachium, is a second oval swelling, the *medial geniculate body*.

The *superior surface* is free, slightly convex, and covered by a layer of white substance, termed the *stratum zonale*. It is separated laterally from the ventricular surface of the caudate nucleus by a white band, the *stria terminalis*, and by the terminal vein. It is divided into a medial and a lateral portion by an oblique shallow furrow which runs from behind forwards and medialwards and corresponds with the lateral margin of the fornix; the lateral

part forms a portion of the floor of the lateral ventricle, and is covered with the ependyma and epithelium of that cavity; the medial part is covered with the tela chorioidea of the third ventricle. In front, the superior surface is separated from the medial surface by a salient margin, the *tænia thalami*, from which the epithelial lining of the third ventricle is reflected to the under surface of the tela chorioidea. Behind, it is limited medially by a groove, the *sulcus habenulæ* which intervenes between it and a small triangular area termed the *trigonum habenulæ*.

FIG. 829.—A coronal section through the brain at the anterior part of the pons. Anterior aspect.



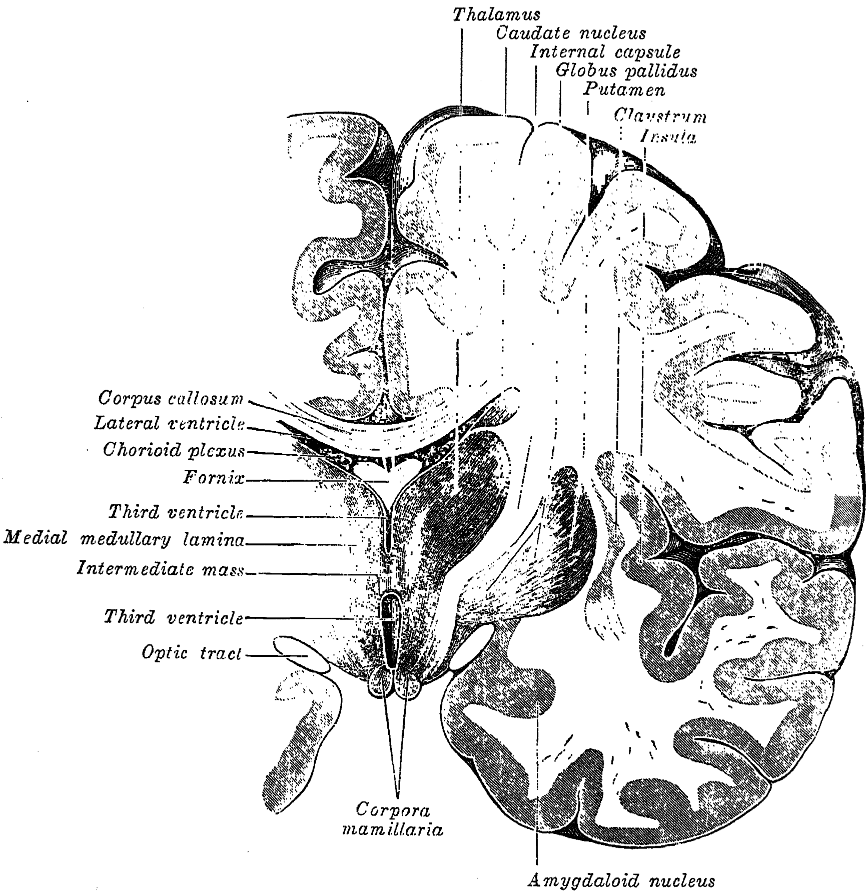
The *inferior surface* rests upon and is continuous with the upward prolongation of the tegmentum (*subthalamic tegmental region*), in front of which it is related to the *substantia innominata of Meynert* (p. 860).

The *medial surface* constitutes the upper part of the lateral wall of the third ventricle; it is covered by a thin layer of grey substance, and is connected to the corresponding surface of the opposite thalamus by a flattened grey band, the *massa intermedia* (middle or grey commissure). This band lies close behind the interventricular foramen, and averages about 1 cm. in its anteroposterior diameter: it sometimes consists of two parts, and occasionally is absent. It contains nerve-cells and nerve-fibres; a few of the latter may cross the middle line, but most of them pass towards the middle line and then curve lateralwards on the same side.

The *lateral surface* is in contact with a thick band of white substance which forms the occipital part of the internal capsule and separates the thalamus from the lentiform nucleus of the corpus striatum.

Structure.—The thalamus consists chiefly of grey substance, but its upper surface is covered by a layer of white substance, named the *stratum zonale*, and its lateral surface by a similar layer termed the *lateral medullary lamina*. Its grey substance is incompletely subdivided into three parts—anterior, medial, and lateral—by a white layer, the *medial medullary lamina*. The anterior part comprises the anterior tubercle, the medial part lies next the lateral wall of the third ventricle, while the lateral and largest part is interposed between the medial and lateral medullary laminæ and includes the pulvinar.

Fig. 830.—A coronal section through the brain, passing through the intermediate mass of the third ventricle. Anterior aspect.

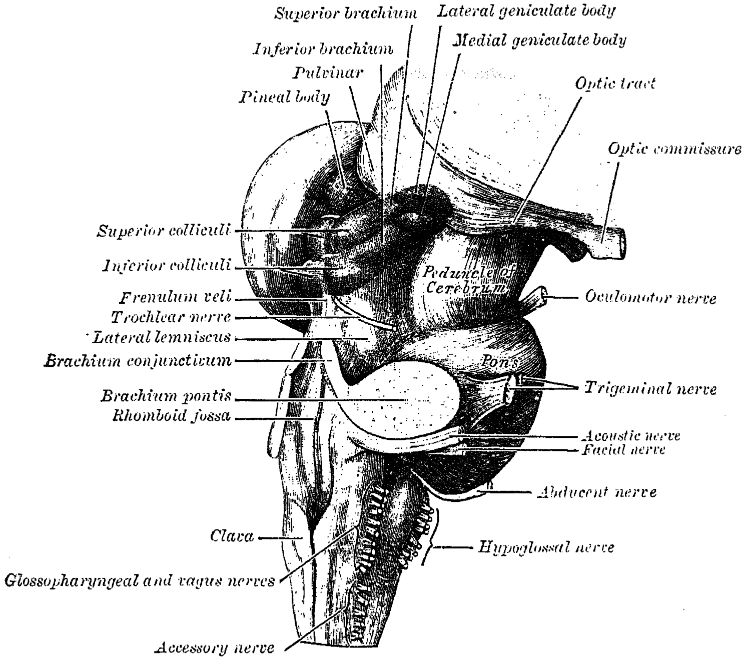


The lateral part is traversed by numerous fibres which radiate from the thalamus into the internal capsule, and pass through the latter to the cerebral cortex. These three parts are built up of numerous nuclei, the connexions of many of which are imperfectly known.

Connexions.—The thalamus may be regarded as a large, ganglionic mass in which the ascending tracts of the tegmentum and a considerable proportion of the fibres of the optic tract end, and from the cells of which numerous fibres (thalamocortical) take origin, and radiate to almost every part of the cerebral cortex. The lemniscus, together with the other longitudinal strands of the tegmentum, enters its ventral part: the thalamomamillary fasciculus (bundle of Vicq d'Azyr), from the corpus mamillare, enters its anterior tubercle, while many of the fibres of the optic tract terminate in its posterior end. The thalamus also receives fibres (corticothalamic) from the cells of the cerebral cortex and others from the red nucleus and the brachium conjunctivum. The fibres arising from the cells of the thalamus form four principal groups or

stalks : (*a*) those of the *anterior stalk* pass from the lateral part of the thalamus through the frontal part of the internal capsule to the frontal lobe ; (*b*) the fibres of the *posterior stalk* (*optic radiations*) arise in the pulvinar and lateral geniculate body, and are conveyed through the occipital part of the internal capsule to the occipital lobe ; (*c*) the fibres of the *inferior stalk* leave the under and medial surfaces of the thalamus, and pass beneath the lentiform nucleus to the temporal lobe and insula ; (*d*) those of the *parietal stalk* pass from the lateral surface of the thalamus to the parietal lobe. Fibres also extend from the thalamus into the caudate and lentiform nuclei of the corpus striatum—those destined for the caudate nucleus leave the lateral surface, and those for the lentiform nucleus the inferior surface, of the thalamus. A large descending fasciculus (thalamo-olivary) ends in the inferior olivary nucleus.

FIG. 831.—The hind-brain and the mid-brain. Posterolateral aspect.



The **metathalamus** (fig. 831) comprises the geniculate bodies, which are two in number—a medial and a lateral—on either side.

The *medial geniculate body* lies under cover of the pulvinar of the thalamus and on the lateral aspect of the corpora quadrigemina. Oval in shape, with its long axis directed forwards and lateralwards, it is lighter in colour and smaller in size than the lateral geniculate body. The inferior brachium from the inferior colliculus disappears under cover of it, while from its lateral extremity a strand of fibres passes to join the optic tract. It receives many acoustic fibres from the lateral lemniscus, and its cells send a relay of similar fibres to the cortex of the temporal lobe. The medial geniculate body is connected with the inferior colliculus of the opposite side by the commissure of Gudden, the fibres of which pass through the posterior part of the optic chiasma and run in the medial parts of the optic tracts.

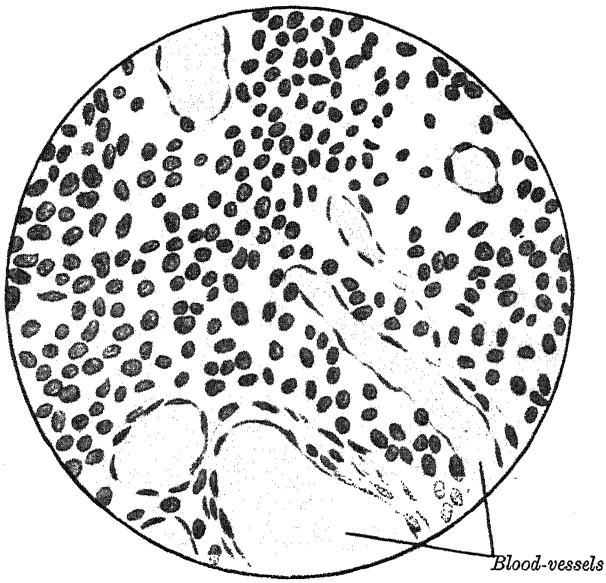
The *lateral geniculate body* is an oval elevation on the lateral part of the posterior end of the thalamus, and is connected with the superior colliculus by the superior brachium. It is of a dark colour, and presents a laminated arrangement consisting of alternate layers of grey and white substance. It receives most of the fibres of the optic tract, but some fibres of this tract pass over or through it into the pulvinar. Its cells are large and pigmented ; their axons pass to the visual area in the occipital part of the cerebral cortex.

The superior colliculus, the pulvinar, and the lateral geniculate body are termed the *lower visual centres.* Extirpation of the eyes in new-born animals entails an arrest of the development of these centres, but has no effect on the medial geniculate bodies or on the inferior colliculi. Moreover, the latter are well developed in the mole, an animal in which the superior colliculi are rudimentary.

The **epithalamus** comprises the trigonum habenulæ, the pineal body, and the posterior commissure.

The *trigonum habenulæ* is a small depressed triangular area situated in front of the superior colliculus and on the lateral aspect of the posterior part of the tænia thalami. It contains a group of nerve-cells termed the *ganglion habenulæ.* Fibres reach this ganglion from the anterior perforated substance through the medullary stria which runs along the junction of the medial with the upper surface of the thalamus; some fibres, forming what is termed the *habenular*

Fig. 832.—A section through the pineal body of a child aged 13 months. Stained with hæmatoxylin and eosin. × 400.



commissure, cross to the ganglion of the opposite side. Most of its fibres are, however, directed downwards and form the *fasciculus retroflexus of Meynert,* which passes medially to the red nucleus, and, after decussating with the corresponding fasciculus of the opposite side, ends in the interpeduncular ganglion.

The *pineal body* (fig. 828) is a small, conical, reddish-grey body which lies in the depression between the superior colliculi. It is placed beneath the splenium of the corpus callosum, but is separated from this by the tela chorioidea of the third ventricle, the lower layer of which envelops it. It measures about 8 mm. in length, and its base, directed forwards, is attached by a stalk or peduncle of white substance. The *stalk* divides anteriorly into two laminæ, a dorsal and a ventral, which are separated from one another by the pineal recess of the third ventricle. The ventral lamina is continuous with the posterior commissure; the dorsal lamina is continuous with the habenular commissure, and divides into two strands, termed the medullary striæ, which run forwards, one on either side, along the junction of the medial and upper surfaces of the thalamus to blend in front with the columns of the fornix.

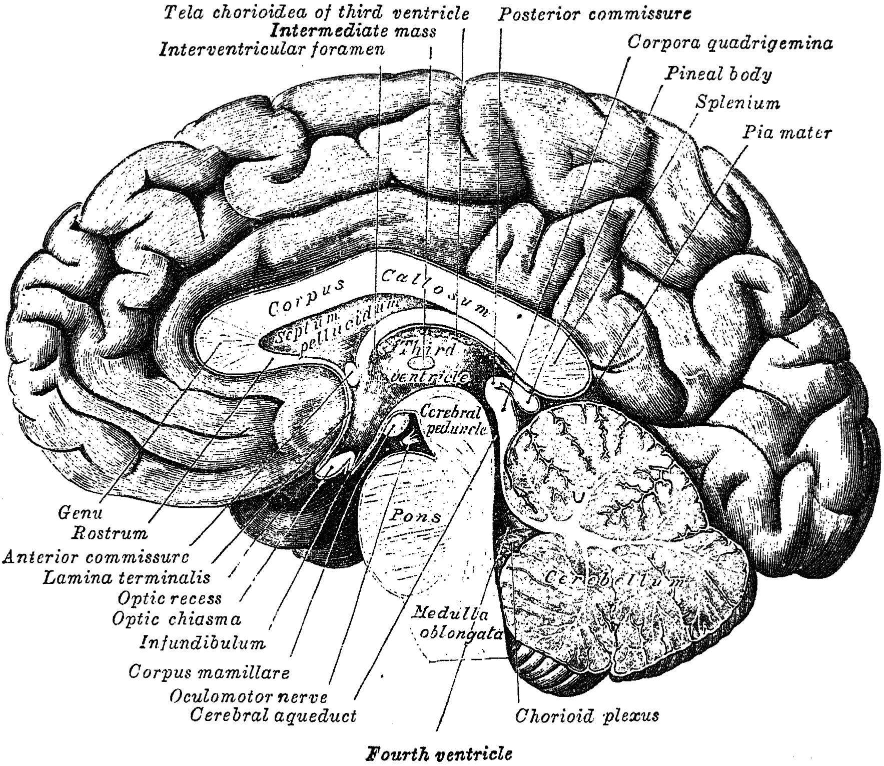
Structure (fig. 832).—The bulk of the parenchyma of the pineal gland consists of rounded cells, the so-called *pineal* cells, with irregular nuclei poor in chromatin. At birth a few neuroglia-cells and nerve-cells are present; the latter have scanty protoplasm and angular nuclei rich in chromatin. Connective tissue cells and fibrils appear during the first year,

and gradually increase in quantity; the rate at which fibrosis takes place is very variable. Calcareous concretions are constantly present in the pineal body after the seventeenth year; spaces or cysts may also be present.*

The human pineal body is phylogenetically homologous with the parietal eye of cyclostome fishes. Creutzfeldt has pointed out that it is best developed in ruminants and horses, but absent in the elephant, seal, dasypus, mole, and many other animals, and he connects its presence with the possession of a relatively thin skin.

Applied Anatomy.—The function of the pineal body in the human body is very uncertain. Probably it has an internal secretion, though this is not proved. Possibly its function is to regulate the pressure of the cerebrospinal fluid. The growth of a tumour in the pineal body, itself of rare occurrence, has led in a few instances to sexual precocity or to obesity. The operative removal of the pineal body from puppies produces no abnormality in their subsequent development.

FIG. 833.—A median sagittal section through the brain. The relations of the pia mater are indicated by the red colour.



The *posterior commissure* is a rounded band of fibres crossing the middle line on the dorsal aspect of the upper end of the cerebral aqueduct. Its fibres acquire their medullary sheaths early, but their connexions have not been definitely determined. Most of them have their origin in a nucleus, the *nucleus of the posterior commissure*, which lies in the central grey substance of the upper end of the cerebral aqueduct, in front of the nucleus of the oculomotor nerve; some are probably derived from the posterior part of the thalamus and from the superior colliculus; others are believed to be continued downwards into the medial longitudinal fasciculus.

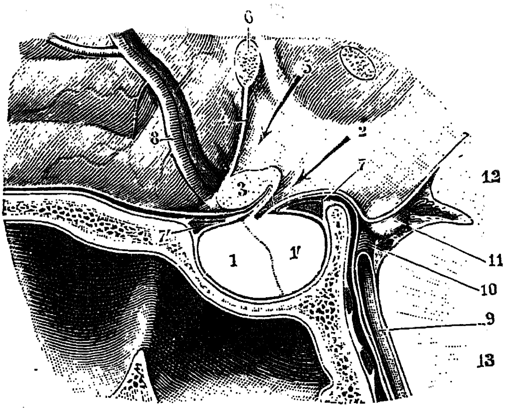
The **hypothalamus** (fig. 833) includes the subthalamic tegmental region and the structures forming the greater part of the floor of the third ventricle, viz. the corpora mamillaria, tuber cinereum, infundibulum, hypophysis, and optic chiasma.

* Consult an abstract of an article by K. H. Krabbe in the *Review of Neurology and Psychiatry*, Edinburgh, 1915, xiii. 300.

The *subthalamic tegmental region* consists of the upward continuation of the tegmentum; it lies on the ventrolateral surface of the thalamus and separates it from the fibres of the internal capsule. The red nucleus and the substantia nigra are prolonged into its lower part; in front it is continuous with the substantia innominata of Meynert (p. 860), medially with the grey substance of the floor of the third ventricle. It consists from above downwards of three strata: (1) *stratum dorsale*, directly applied to the under surface of the thalamus and consisting of fine longitudinal fibres; (2) *zona incerta*, a continuation forwards of the formatio reticularis of the tegmentum; and (3) the *corpus subthalamicum* or *nucleus of Luys*, a brownish mass presenting a lenticular shape on transverse section, and situated on the dorsal aspect of the fibres of the base of the cerebral peduncle; it is encapsuled by a lamina of nerve-fibres and contains numerous medium-sized nerve-cells the connexions of which are as yet not fully determined.

The *corpora mamillaria* are two round white masses, each about the size of a small pea, placed side by side below the grey substance of the floor of the third ventricle in front of the posterior perforated substance. Each consists of white substance externally and of grey substance internally, the cells of the latter forming two nuclei, a *medial* of small and a *lateral* of large cells. The white substance is mainly formed by the fibres of the columns of the fornix, which descend to the base of the brain and end partly in the corpora mamillaria. From the cells of the medial nucleus a bundle of fibres arises and divides into a *mamillothalamic fasciculus* (bundle of Vicq d'Azyr) which passes upwards into the anterior nucleus of the thalamus, and a *mamillotegmental fasciculus* which is directed downwards into the tegmentum. Afferent fibres are conveyed to the lateral nucleus from the tegmentum.

Fig. 834.—A sagittal section through the hypophysis cerebri, in situ. Schematic. (Testut.)



1, 1'. Anterior and posterior lobes of hypophysis. 2. Infundibulum. 3. Optic chiasma. 4. Lamina terminalis. 5. Optic recess. 6. Anterior commissure. 7, 7'. Circular sinus. 8. Anterior cerebral artery. 9. Basilar artery. 10. Posterior cerebral artery. 11. Corpus mamillare. 12. Cerebral peduncle. 13. Pons.

The *tuber cinereum* is a hollow eminence of grey substance situated between the corpora mamillaria behind, and the optic chiasma in front. Laterally it is continuous on either side with the anterior perforated substance, and anteriorly with a thin lamina, the *lamina terminalis*. From the under surface of the tuber cinereum a hollow conical process, the *infundibulum*, projects downwards and forwards and is attached to the posterior lobe of the hypophysis.

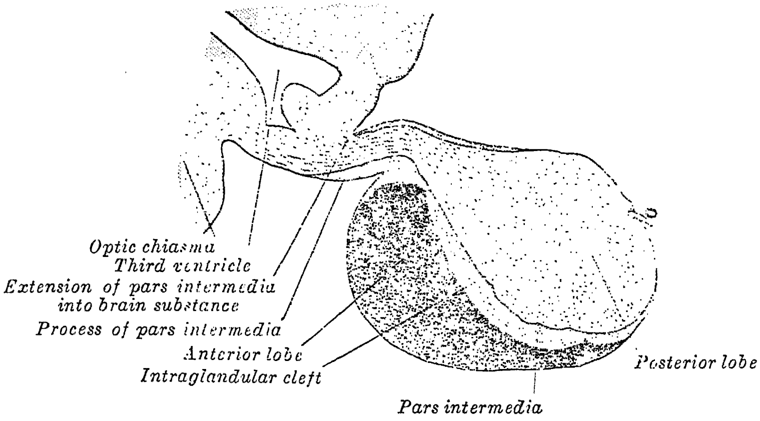
In the lateral part of the tuber cinereum is a nucleus of nerve-cells, the *basal optic nucleus of Meynert*, and close to the cavity of the third ventricle are three additional nuclei.

Between the tuber cinereum and the corpora mamillaria a small elevation, with a corresponding depression in the third ventricle, is sometimes seen. Retzius has named it the *eminentia saccularis* and regards it as a representative of the saccus vasculosus found in some of the lower vertebrates.

The *hypophysis* (pituitary body) (fig. 834) is a reddish-grey, somewhat ovoid mass, measuring about 12 mm. in its transverse, and 8 mm. in its antero-posterior, diameter. It is attached to the end of the infundibulum, and is situated in the fossa hypophyseos of the sphenoidal bone, where it is retained by a circular fold of dura mater, the *diaphragma sellæ*; this fold almost completely roofs in the fossa, leaving only a small central aperture through which the infundibulum passes.

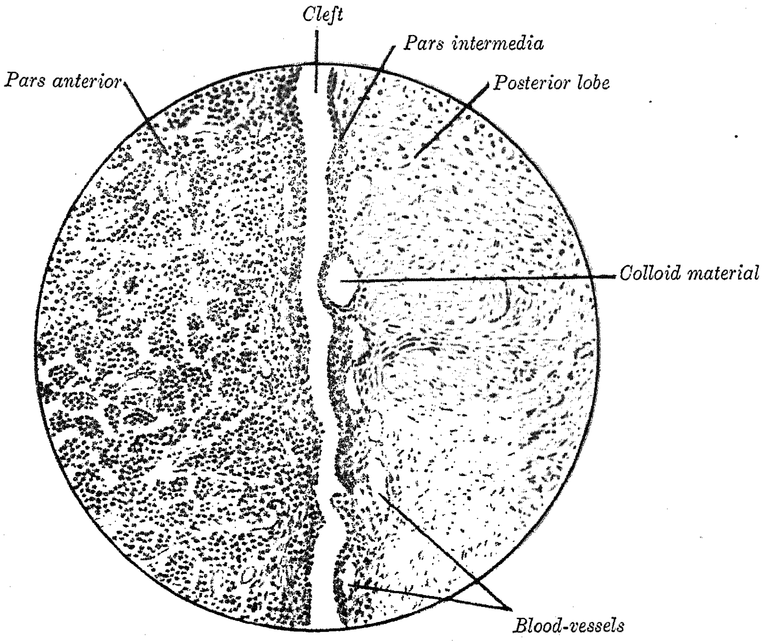
The hypophysis consists of an anterior and a posterior lobe, which differ in their development and structure (fig. 835). The *anterior lobe* is the larger, and is somewhat kidney-shaped, the concavity being directed backwards and embracing the posterior lobe. It is developed from a diverticulum of

FIG. 835.—A median sagittal section through the hypophysis of an adult monkey. Semidiagrammatic. (Herring.)



the ectoderm of the primitive buccal cavity or stomodæum (p. 135), and consists of a pars anterior and a pars intermedia, separated from each other by a narrow cleft, the remnant of the diverticulum. The *pars anterior* is extremely vascular and consists of granular epithelial cells of varying

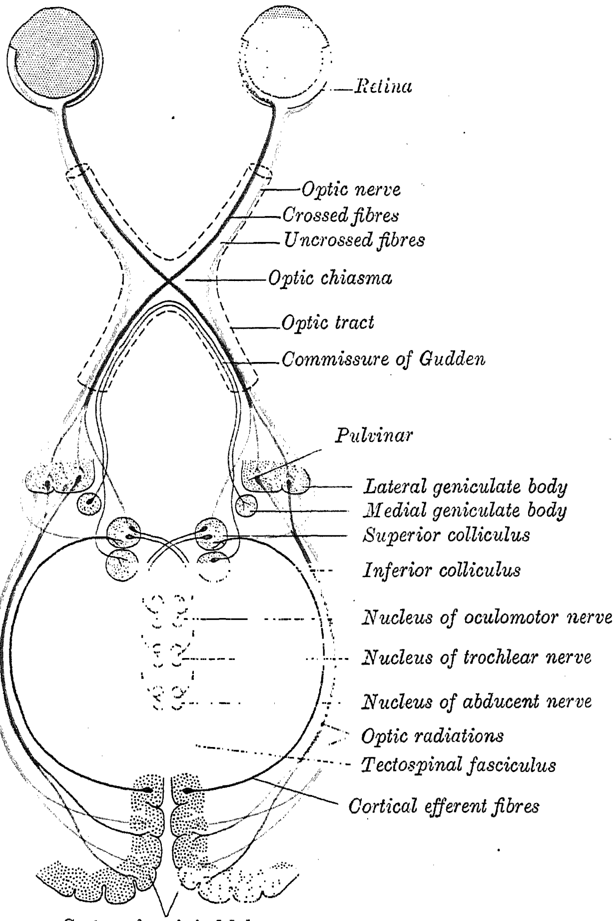
FIG. 836.—A section of the hypophysis. ×100.



size and shape, arranged in cord-like trabeculæ or alveoli and separated by large, thin-walled blood-vessels. The *pars intermedia* is a thin lamina closely applied to the body and neck of the posterior lobe; it contains a few blood-vessels and consists of finely granular cells between which are small

masses of colloid material. The *posterior lobe* is developed as a downgrowth from the floor of the embryonic brain, and during early fœtal life contains a cavity continuous with that of the third ventricle. In some animals (e.g. cat) this cavity persists throughout life. Although of nervous origin the posterior lobe contains no nerve-cells or fibres. It consists of neuroglia-cells and fibres, and is invaded by cell-columns which grow into it from the pars intermedia; imbedded in it are scattered masses of a colloid substance histologically similar to that found in the thyreoid gland. In certain of the lower vertebrates (e.g. fishes) nervous structures are present, and the lobe is of large size.

FIG. 837.—A scheme showing the central connexions of the optic nerves and optic tracts.



Applied Anatomy.—Sharpey Schafer has isolated from the pars intermedia a substance, no doubt an internal secretion, that causes constriction of the blood-vessels, rise of arterial blood-pressure, and increased secretion of urine, when injected subcutaneously. The anterior lobe is said "to control calcium metabolism and the growth of the skeleton." Enlargement of the hypophysis and of the cavity of the sella turcica is found in the rare disease *acromegaly*, which is characterised by gradual increase of the size of the face, hands, and feet, with headache and often a peculiar type of blindness. This blindness is due to the pressure of the enlarging hypophysis on the optic chiasma (fig. 834). The pressure causes atrophy of the nerve-fibres coming from the nasal sides of the retinæ; with the result that the patient loses his two temporal fields of vision while retaining his nasal fields (bitemporal hemianopsia).

Optic chiasma.—The optic chiasma (fig. 798) is a flattened, somewhat quadrilateral band of fibres, situated at the junction of the floor and anterior wall of

the third ventricle. Most of its fibres have their origins in the retinæ, and reach the chiasma through the optic nerves, which are continuous with its anterolateral angles. In the chiasma the fibres from the nasal half of the retina cross the middle line and enter the optic tract of the opposite side, while the fibres from the temporal half of the retina do not cross, but pass back into the optic tract of the same side. In the posterior part of the commissure there is a strand of fibres, the *commissure of Gudden*, which is not derived from the optic nerves; it forms a connecting link between the medial geniculate body and the inferior colliculus of the opposite side.

Optic tracts.—The optic tracts (figs. 798, 837) are continued backwards and lateralwards from the posterolateral angles of the optic chiasma. Each passes between the anterior perforated substance and the tuber cinereum, and, winding round the ventrolateral aspect of the cerebral peduncle, divides into a medial and a lateral root. The medial root comprises the fibres of Gudden's commissure. The lateral root consists mainly of afferent fibres which arise in the retina and undergo partial decussation in the optic chiasma, as described; but it also contains a few fine efferent fibres which have their origins in the brain and their terminations in the retina. When traced backwards, the afferent fibres of the lateral root are found to end in the lateral geniculate body and pulvinar of the thalamus, and in the superior colliculus; and these three structures constitute the *lower visual centres*. Fibres arise from the nerve-cells in the lateral geniculate body and pulvinar, and pass through the occipital part of the internal capsule, under the name of the *optic radiations*, to the cortex of the occipital lobe of the cerebrum, where the *higher or cortical visual centre* is situated. Some of the fibres of the optic radiations take an opposite course, arising from the cells of the occipital cortex and passing to the superior colliculus. Some fibres from the superior colliculus cross the median plane and then pass to the nuclei of the oculomotor, trochlear, and abducent nerves. Some fibres reach the cerebellum through the brachia conjunctiva; others (tectospinal) descend into the spinal medulla.

The Third Ventricle

The **third ventricle** (figs. 828, 833, 838) is a median cleft between the two thalami. Behind, it communicates with the fourth ventricle through the cerebral aqueduct, and in front with the lateral ventricles through the interventricular foramen. Somewhat triangular in shape with the apex directed backwards, it has a roof, a floor, an anterior and a posterior boundary, and two lateral walls.

The *roof* (fig. 838) is formed by a layer of epithelium, which stretches between the upper edges of the lateral walls of the cavity and is continuous with the epithelial lining of the ventricle. It is covered by and adherent to a fold of pia mater, named the tela chorioidea of the third ventricle, from the under surface of which a pair of vascular fringed processes, the *chorioid plexuses of the third ventricle*, project downwards, one on either side of the middle line, and invaginate the epithelial roof into the ventricular cavity.

The *floor* slopes downwards and forwards and is formed mainly by the structures which constitute the hypothalamus: from before backwards these are: the optic chiasma, the infundibulum and tuber cinereum, and the corpora mamillaria. Behind the last, the floor is formed by the posterior perforated substance and by the tegmenta of the cerebral peduncles. The ventricle is prolonged downwards as a funnel-shaped recess, the *recessus infundibuli*, into the infundibulum, to the apex of which the hypophysis is attached.

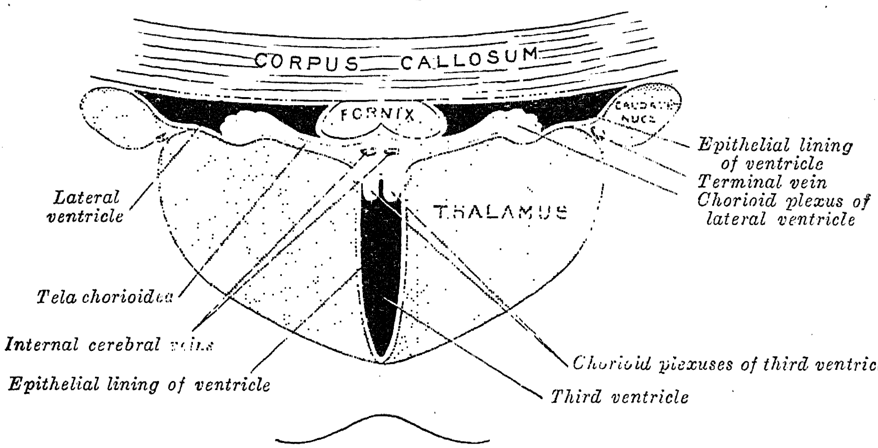
The *anterior boundary* is constituted below by the *lamina terminalis*, a thin layer of grey substance stretching from the upper surface of the optic chiasma to the rostrum of the corpus callosum; above by the columns of the fornix and the anterior commissure. At the junction of the floor and anterior wall, immediately above the optic chiasma, the ventricle presents a small angular recess or diverticulum, the *optic recess*. Between the columns of the fornix, and above the anterior commissure, is a second recess termed the *vulva*. At the junction of the roof with the anterior and lateral walls of the ventricle, and situated between the thalami behind and the columns of the fornix in

front, is the *interventricular foramen* (foramen of Monro) through which the third ventricle communicates with the lateral ventricles.

The *posterior boundary* is constituted by the pineal body, the posterior commissure and the cerebral aqueduct. A small recess, the *recessus pinealis*, projects into the stalk of the pineal body, whilst in front of and above the pineal body is a second recess, the *recessus suprapinealis*, consisting of a diverticulum of the epithelium which forms the ventricular roof.

Each *lateral wall* consists of an upper portion formed by the medial surface of the anterior two-thirds of the thalamus, and a lower consisting of an upward continuation of the grey substance of the ventricular floor. These two parts correspond to the alar and basal laminæ of the lateral wall of the

Fig. 838.—A coronal section through the lateral and third ventricles. Diagrammatic.



fore-brain vesicle and are separated from each other by a furrow, the *sulcus of Monro*, which extends from the interventricular foramen (p. 863) to the cerebral aqueduct. The lateral wall is limited above by the tænia thalami. The columns of the fornix curve downwards in front of the interventricular foramen, and then run in the lateral walls of the ventricle, where, at first, they form distinct prominences, but subsequently are lost to sight. The lateral walls are joined to each other across the cavity of the ventricle by a band of grey matter, the *massa intermedia* (p. 833).

The **interpeduncular fossa** (figs. 798, 839).—This is a somewhat lozenge-shaped area of the base of the brain, limited in front by the optic chiasma, behind by the anterosuperior surface of the pons, anterolaterally by the converging optic tracts and posterolaterally by the diverging cerebral peduncles. The structures contained in it have already been described ; from behind forwards they are the posterior perforated substance (p. 825), corpora mamillaria tuber cinereum, infundibulum, and hypophysis (p. 838).

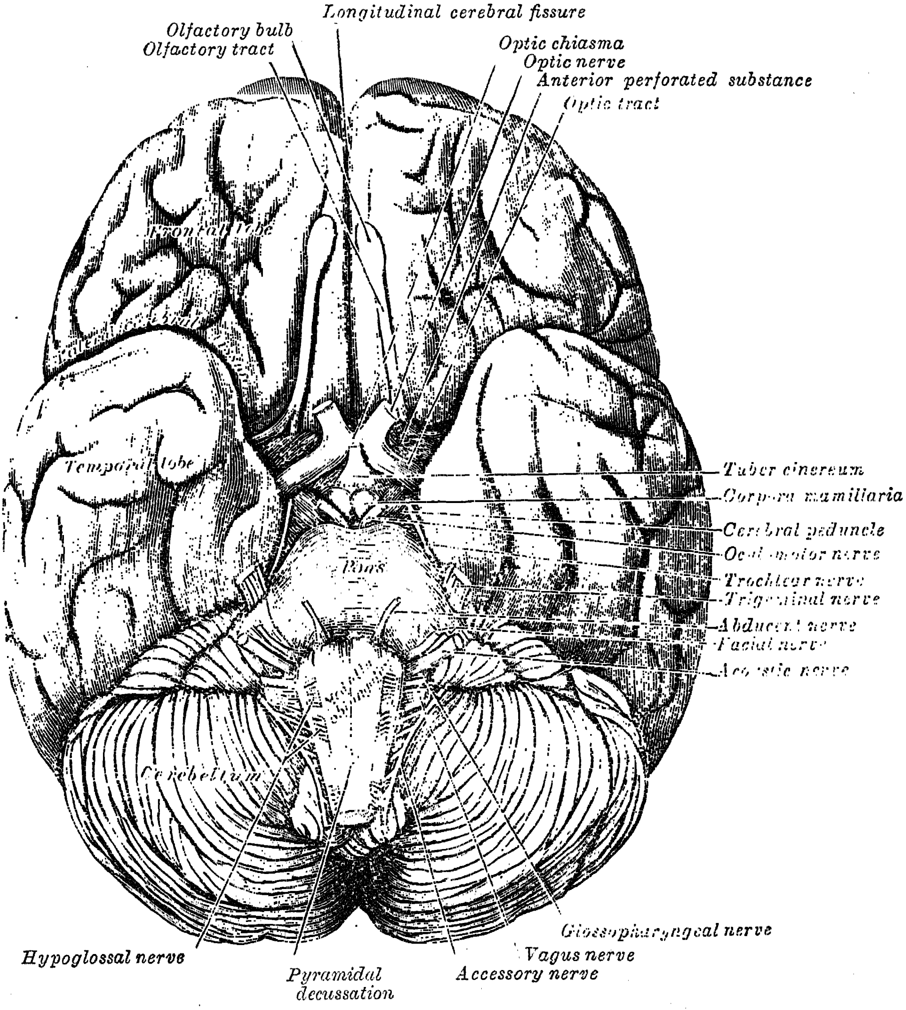
The Telencephalon

The **telencephalon** includes : (1) the cerebral hemispheres with their cavities, the lateral ventricles ; and (2) the pars optica hypothalami and the anterior portion of the third ventricle (already described under the diencephalon). As intimated in the chapter on Embryology (p. 95), each cerebral hemisphere may be divided into three fundamental parts, viz. the rhinencephalon, the corpus striatum, and the neopallium. The rhinencephalon, associated with the sense of smell, is the oldest part of the telencephalon, and forms almost the whole of the hemisphere in some of the lower animals (e.g. fishes, amphibians, and reptiles). In man it is rudimentary, whereas the neopallium undergoes great development and forms the chief part of the hemisphere.

The Cerebral Hemispheres

The **cerebral hemispheres** constitute the largest part of the brain, and, when viewed together from above, assume the form of an ovoid mass broader behind than in front, the greatest transverse diameter corresponding with a line connecting the two parietal tuberosities. The hemispheres are separated by a deep median cleft, named the *longitudinal cerebral fissure*, and each possesses a central cavity, the lateral ventricle.

Fig. 839.—The base of the brain.



The **longitudinal cerebral fissure** contains a sickle-shaped process of dura mater, the falx cerebri. In front and behind, the fissure completely separates the cerebral hemispheres from one another ; in the middle, however, it only extends down to a great central white commissure, the *corpus callosum*, which connects the hemispheres across the median plane.

In a median sagittal section (fig. 833) the cut corpus callosum presents the appearance of a broad, arched band. Its thick posterior end, termed the *splenium*, overlaps the mid-brain, but is separated from it by the tela chorioidea of the third ventricle and the pineal body. Its anterior curved end, termed the *genu*, gradually tapers into a thinner portion, the *rostrum*, which is continued

downwards and backwards in front of the anterior commissure to join the lamina terminalis. Arching backwards from immediately behind the anterior commissure to the under surface of the splenium is a second white band named the *fornix*; between this and the corpus callosum are the laminæ and cavity of the septum pellucidum.

The Surfaces of the Cerebral Hemispheres

Each cerebral hemisphere presents three surfaces: lateral, medial, and inferior.

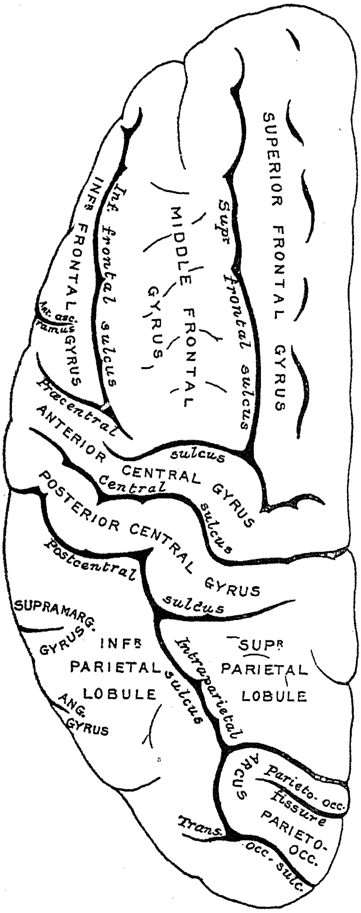


Fig. 840.—The lateral surface of the left cerebral hemisphere. Superior aspect.

The *lateral surface* is convex in adaptation to the concavity of the corresponding half of the vault of the cranium. The *medial surface* is flat and vertical and is separated from that of the opposite hemisphere by the longitudinal fissure and the falx cerebri. The *inferior surface* is of an irregular form, and may be divided into three areas: anterior, middle, and posterior. The anterior area, formed by the orbital surface of the frontal lobe, is concave, and rests on the roof of the orbit and nose; the middle area is convex, and consists of the under surface of the temporal lobe: it is adapted to the corresponding half of the middle cranial fossa. The posterior area is concave, directed medialwards and downwards, and is named the *tentorial surface*, since it rests upon the tentorium cerebelli, which intervenes between it and the upper surface of the cerebellum.

The three surfaces are separated by the following borders: (*a*) *superomedial*, between the lateral and medial surfaces; (*b*) *inferolateral*, between the lateral and inferior surfaces; the anterior part of this border separates the lateral from the orbital surface of the frontal lobe, and is known as the *superciliary* border; (*c*) *medial occipital*, between the tentorial and medial surfaces; and (*d*) *medial orbital*, separating the orbital from the medial surface. The anterior end of the hemisphere is named the *frontal pole*; the posterior, the *occipital pole*; and the anterior end of the temporal lobe, the *temporal pole*. About 5 cm. in front of the occipital pole on the inferolateral border is an indentation or notch, named the *pre-occipital notch*.

The surfaces of the hemispheres are moulded into a number of irregular eminences, named *gyri* or *convolutions*, and separated by furrows termed *fissures* and *sulci*.

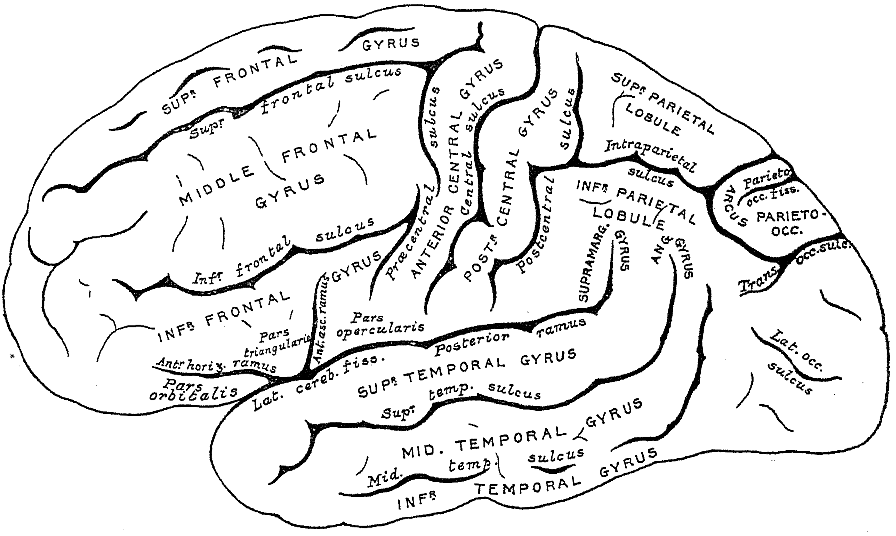
The gyri and their intervening fissures and sulci are fairly constant in their arrangement; at the same time they vary within certain limits, not only in different individuals, but on the two hemispheres of the same brain. The convoluted condition of the surface permits of a great increase of the grey matter without the sacrifice of much additional space, and the number and extent of the gyri, as well as the depth of the intervening furrows, appear to bear a direct relation to the intellectual powers of the individual.

Certain of the fissures and sulci are utilised for the purpose of dividing the hemisphere into lobes, and are therefore termed *interlobar*; included under

this category are the lateral cerebral, parieto-occipital, calcarine and collateral fissures, and the central, cingulate, subparietal and circular sulci.

The lateral cerebral fissure (fissure of Sylvius) (figs. 839, 841) is a well-marked cleft on the inferior and lateral surfaces of the hemisphere, and consists of a short stem which divides into three rami. The *stem* is situated on the base of the brain (fig. 839), and commences in a depression at the lateral angle of the anterior perforated substance. From this point it extends between the anterior part of the temporal lobe and the orbital surface of the frontal lobe, and reaches the lateral surface of the hemisphere. Here it divides into three rami: an anterior horizontal, an anterior ascending, and a posterior. The *anterior horizontal ramus* passes forwards for about 2·5 cm. into the inferior frontal gyrus, while the *anterior ascending ramus* extends upwards for about an equal distance into the same convolution. The *posterior ramus* is the longest; it runs backwards and slightly upwards for about 7 cm., and ends by an upward inflexion in the parietal lobe.

FIG. 841.—The lateral surface of the left cerebral hemisphere.



The parieto-occipital fissure.—Only a small part of this fissure is seen on the lateral surface of the hemisphere, its chief part being on the medial surface. The *lateral part* (fig. 841) is situated about 5 cm. in front of the occipital pole of the hemisphere, and is about 1·25 cm. long. The *medial part* (fig. 842) runs downwards and forwards as a deep cleft on the medial surface of the hemisphere, and joins the calcarine fissure below and behind the posterior end of the corpus callosum. In most cases it contains a submerged gyrus.

The calcarine fissure (fig. 842) is on the medial surface of the hemisphere. It begins near the occipital pole in two converging rami, and runs forward, at first with an upward, and then with a downward curve; it ends in the posterior part of the gyrus hippocampi, just below the splenium of the corpus callosum; a little behind the splenium it is joined at an acute angle by the medial part of the parieto-occipital fissure. The anterior part of the calcarine fissure gives rise to the prominence of the calcar avis in the posterior cornu of the lateral ventricle (p. 856).

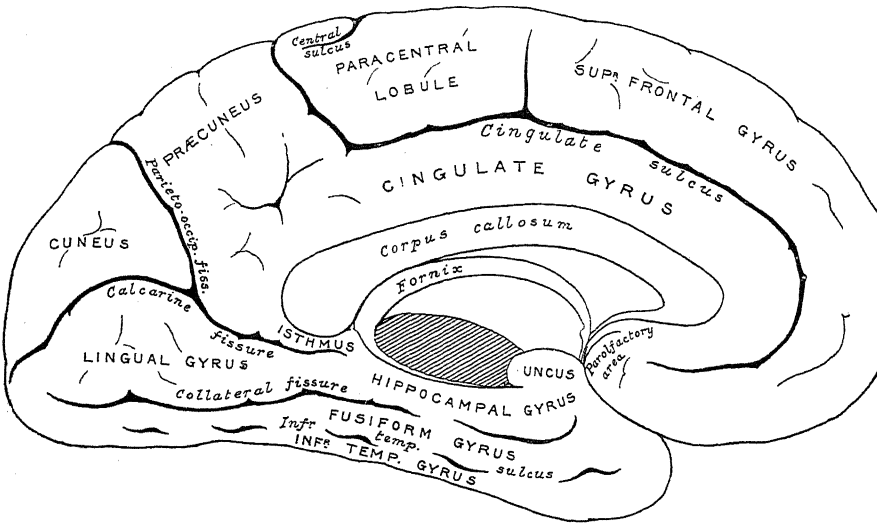
The collateral fissure (fig. 842) is on the tentorial surface of the hemisphere, and extends from near the occipital pole to within a short distance of the temporal pole. Behind, it lies below and lateral to the calcarine fissure, from which it is separated by the lingual gyrus; in front, it is situated between the hippocampal gyrus and the anterior part of the fusiform gyrus.

The central sulcus (fissure of Rolando) (figs. 840, 841) is situated about the middle of the lateral surface of the hemisphere, and begins in or near the

longitudinal cerebral fissure, a little behind the midpoint between the frontal and occipital poles. It runs sinuously downwards and forwards, and ends a little above the posterior ramus of the lateral fissure, and about 2·5 cm. behind the anterior ascending ramus of the same fissure. It describes two chief curves: a *superior genu* with its concavity directed forwards, and an *inferior genu* with its concavity directed backwards. The central sulcus forms an angle, opening forwards, of about 70° with the median plane.

The **cingulate sulcus** (fig. 842) is on the medial surface of the hemisphere. It begins below the rostrum of the corpus callosum, curves in front of its genu, is continued backwards above its body, and finally ascends to the superomedial border of the hemisphere a short distance behind the upper end of the central sulcus. It separates the cingulate gyrus from the superior frontal gyrus and the paracentral lobule.

FIG. 842.—The medial surface of the left cerebral hemisphere.



The **subparietal sulcus** is a short sulcus on the medial surface of the hemisphere, in line with but separate from the cingulate sulcus. It intervenes between the præcuneus and the cingulate gyrus.

The **circular sulcus** (sulcus limitans insulæ) (fig. 845) is on the lower and lateral surfaces of the hemisphere. It surrounds the insula (p. 849) and separates it from the frontal, parietal, and temporal lobes.

Lobes of the hemispheres.—By means of these fissures and sulci, assisted by certain arbitrary lines, each hemisphere is divided into the following lobes: *frontal*, *parietal*, *temporal*, *occipital*, *limbic*, and the *insula*.

The **frontal lobe.**—On the lateral surface of the hemisphere this lobe extends from the frontal pole to the central sulcus, the latter separating it from the parietal lobe; below, it is limited by the posterior ramus of the lateral fissure, which intervenes between it and the temporal lobe. On the medial surface, it is separated from the cingulate gyrus by the cingulate sulcus; and on the inferior surface, it is bounded behind by the stem of the lateral cerebral fissure.

The *lateral surface* of the frontal lobe (fig. 841) is traversed by three sulci which divide it into four gyri; the sulci are named the precentral, and the superior and inferior frontal; the gyri are the anterior central, and the superior, middle, and inferior frontal. The *precentral sulcus* runs parallel to the central sulcus, and is usually divided into an upper and a lower part; between it and the central sulcus is the anterior central gyrus. From the precentral sulcus, the *superior* and *inferior frontal sulci* run forwards and downwards, and divide the remainder of the lateral surface of the lobe into three parallel gyri, named the superior, middle, and inferior frontal gyri.

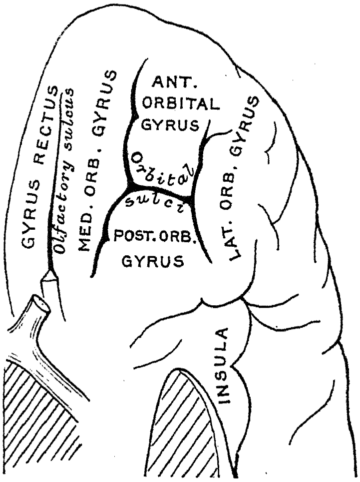
The *anterior central gyrus* is bounded in front by the precentral sulcus, behind by the central sulcus; it extends from the superomedial border of the hemisphere to the posterior ramus of the lateral cerebral fissure.

The *superior frontal gyrus* is situated above the superior frontal sulcus and is continued on to the medial surface of the hemisphere. The portion on the lateral surface of the hemisphere is more or less completely subdivided into an upper and a lower part by the *paramedial sulcus*, which, however, is frequently interrupted by bridging gyri.

The *middle frontal gyrus*, between the superior and inferior frontal sulci, is continuous with the anterior orbital gyrus on the inferior surface of the frontal lobe; it is frequently subdivided into two by the *medial frontal sulcus* of Eberstaller, which ends anteriorly in a wide bifurcation.

The *inferior frontal gyrus* lies below the inferior frontal sulcus, and is continuous with the lateral and posterior orbital gyri on the inferior surface of the frontal lobe. The anterior horizontal and ascending rami of the lateral cerebral fissure subdivide it into three parts, viz.: (1) *pars orbitalis*, below the anterior horizontal ramus of the fissure; (2) *pars triangularis* ('cap' of Broca), between the ascending and horizontal rami; and (3) *pars basilaris*, behind the anterior ascending ramus. The left inferior frontal gyrus is, as a rule, more highly developed than the right, and is named the *gyrus of Broca*, from the fact that Broca described it as the centre for articulate speech.

Fig. 843.—The orbital surface of the left frontal lobe.



The *inferior or orbital surface* of the frontal lobe (fig. 843) is concave, and rests on the orbital plate of the frontal bone. It is divided by an H-shaped *orbital sulcus* into four gyri. These are named, from their position, the *medial, anterior, lateral*, and *posterior orbital gyri*. The medial orbital gyrus is traversed by an anteroposterior sulcus, the *olfactory sulcus*, for the olfactory tract; the portion medial to this is named the *gyrus rectus*, and is continuous with the superior frontal gyrus on the medial surface.

The *medial surface* of the frontal lobe is occupied by the medial part of the superior frontal gyrus (marginal gyrus) (fig. 842). It lies between the cingulate sulcus and the superomedial margin of the hemisphere. The posterior part of this gyrus is named the *paracentral lobule*, and is continuous, over the superomedial border of the hemisphere, with the anterior and posterior central gyri.

The **parietal lobe.**—The parietal lobe is separated from the frontal lobe by the central sulcus, but its boundaries below and behind are not so definite. Posteriorly, it is limited by the lateral part of the parieto-occipital fissure, and by a line carried across the hemisphere from the lateral end of this fissure to the pre-occipital notch. It is separated from the temporal lobe by the posterior ramus of the lateral fissure, and by a line carried backwards from this ramus to meet the line passing downwards to the pre-occipital notch. It has a lateral and a medial surface.

The *lateral surface* of the parietal lobe (fig. 841) is cleft by the *intraparietal sulcus* (Turner), which consists of an oblique and a horizontal portion. The oblique part is named the *postcentral sulcus*, and commences below, about midway between the lower end of the central sulcus and the upturned end of the lateral fissure. It runs upwards and backwards, parallel to the central sulcus, and is sometimes divided into an *upper* and a *lower* ramus. It forms the hinder limit of the posterior central gyrus.

From about the middle of the postcentral sulcus, or from the upper end of its inferior ramus, the *horizontal portion* of the intraparietal sulcus is carried backwards and slightly upwards on the parietal lobe, and is prolonged, under

the name of the *occipital ramus*, into the occipital lobe, where it divides into two parts, which form nearly a right angle with the main stem and constitute the *transverse occipital sulcus*. The part of the parietal lobe above the horizontal portion of the intraparietal sulcus is named the superior parietal lobule; the part below, the inferior parietal lobule.

The *posterior central gyrus* extends from the superomedial border of the hemisphere to the posterior ramus of the lateral fissure. It lies behind the central sulcus, parallel with the anterior central gyrus, with which it is continuous below, and sometimes also above, the central sulcus.

The *superior parietal lobule* is bounded in front by the upper part of the postcentral sulcus, but is usually connected with the posterior central gyrus above the end of the sulcus; behind it, is the lateral part of the parieto-occipital fissure, round the end of which it is joined to the occipital lobe by a curved gyrus, the *arcus parieto-occipitalis*; below, it is separated from the inferior parietal lobule by the horizontal portion of the intraparietal sulcus.

The *inferior parietal lobule* lies below the horizontal portion of the intraparietal sulcus, and behind the lower part of the postcentral sulcus. It is divided into two gyri. One, the *supramarginal gyrus*, arches over the upturned end of the lateral fissure; it is continuous in front with the postcentral gyrus, and behind and below with the superior temporal gyrus; it is occasionally bounded behind by a small sulcus, the *sulcus intermedius primus*, which descends from the horizontal part of the intraparietal sulcus. The other, the *angular gyrus*, arches over the posterior end of the superior temporal sulcus, behind and below which it is continuous with the middle temporal gyrus; sometimes a small *sulcus intermedius secundus* forms its posterior boundary.

The *medial surface* of the parietal lobe (fig. 842) is bounded behind by the medial part of the parieto-occipital fissure; in front, by the posterior end of the cingulate sulcus; below, it is separated from the cingulate gyrus by the *subparietal sulcus*. It consists of a square-shaped convolution, termed the *præcuneus* or *quadrate lobe*.

The **occipital lobe.**—The occipital lobe, small and pyramidal in shape, has three surfaces: lateral, medial, and tentorial.

The *lateral surface* of the occipital lobe (fig. 841) is limited in front by the lateral part of the parieto-occipital fissure, and by a line carried from the end of this fissure to the pre-occipital notch; it is traversed by the transverse occipital and the lateral occipital sulci. The *transverse occipital sulcus* is continuous with the posterior end of the occipital ramus of the intraparietal sulcus, and runs across the upper part of the lobe, a short distance behind the parieto-occipital fissure. The *lateral occipital sulcus* extends from behind forwards, and divides the lateral surface of the occipital lobe into a *superior* and an *inferior gyrus*, which are continuous in front with the parietal and temporal lobes. A vertical gyrus, which runs along the posterior border of this surface to the occipital pole, has been described as the *gyrus descendens* (Ecker).

The *medial surface* of the occipital lobe (fig. 842) is bounded in front by the medial part of the parieto-occipital fissure, and is traversed by the calcarine fissure, which subdivides it into the cuneus and the lingual gyrus. The *cuneus* is a wedge-shaped area between the calcarine fissure and the medial part of the parieto-occipital fissure. The *lingual gyrus* lies between the calcarine fissure and the posterior part of the collateral fissure; behind, it reaches the occipital pole; in front, it joins the hippocampal gyrus.

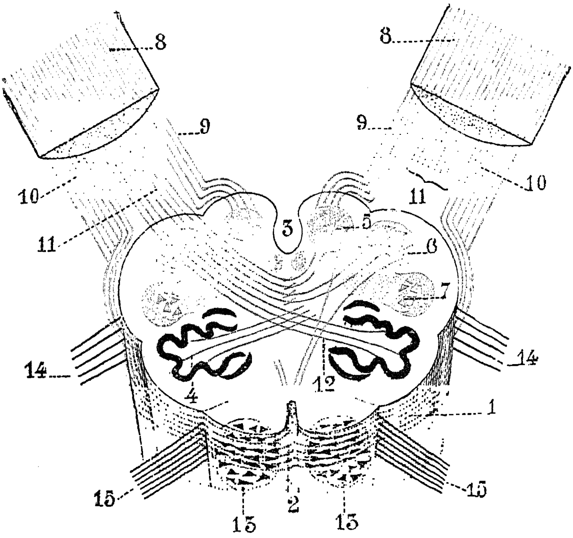
The *tentorial surface* of the occipital lobe is limited in front by an imaginary transverse line through the pre-occipital notch, and consists of the posterior part of the fusiform gyrus (p. 849), and the lower part of the lingual gyrus, which are separated from each other by the posterior segment of the collateral fissure.

The **temporal lobe.**—The temporal lobe has superior, lateral, and inferior surfaces.

The *superior surface* forms the lower limit of the lateral cerebral fissure and overlaps the insula. Three or four gyri spring from the depth of the hinder end of the fissure, and run obliquely forwards and lateralwards on the posterior part of the upper surface of the superior temporal gyrus; these are named the *transverse temporal gyri* (Heschl) (fig. 844).

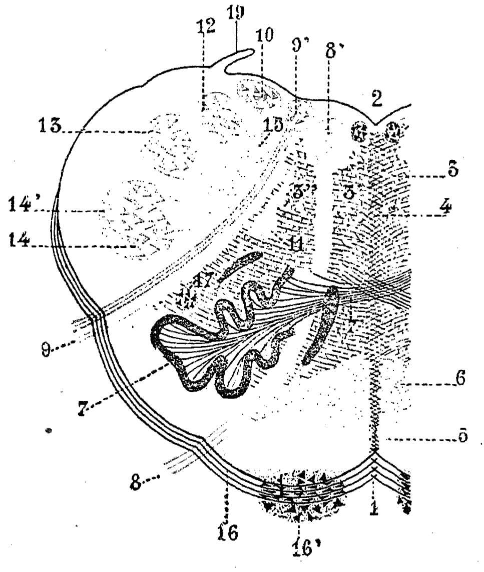
The *lateral surface* (fig. 841) is bounded above by the posterior ramus of the lateral fissure, and by an imaginary line continued backwards from it; below,

Fig. 811.—A scheme showing the course of the arcuate fibres. (Testut.)



1. Medulla oblongata, anterior surface. 2. Anterior median fissure. 3. Fourth ventricle. 4. Inferior olivary nucleus, with the accessory olivary nuclei. 5. Nucleus gracilis. 6. Nucleus cuneatus. 7. Spinal tract and nucleus of trigeminal nerve. 8. Restiform bodies. 9. Posterior external arcuate fibres. 10. Anterior external arcuate fibres. 11. Olivo-cerebellar fasciculus. 12. Peduncle of inferior olivary nucleus. 13. Nucleus arcuatus. 14. Vagus nerve. 15. Hypoglossal nerve.

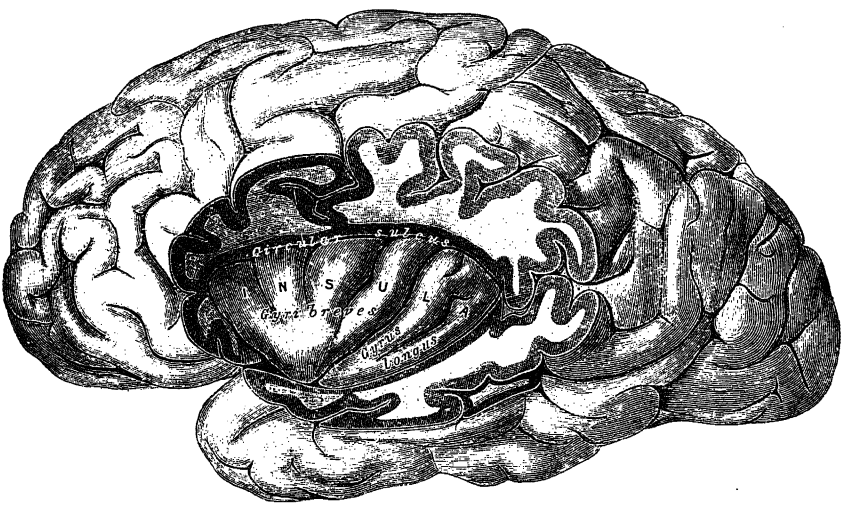
Fig. 812.—A transverse section of the medulla oblongata through the middle of the olive, showing the formatio reticularis. Schematic. (Testut.)



1. Anterior median fissure. 2. Fourth ventricle. 3. Formatio reticularis, with 3′, its internal part (reticularis alba), and 3″, its external part (reticularis grisea). 4. Raphe. 5. Pyramid. 6. Lemniscus. 7. Inferior olivary nucleus, with the two accessory olivary nuclei. 8. Hypoglossal nerve, with 8′, its nucleus of origin. 9. Vagus nerve, with 9′, its nucleus of termination. 10. Medial vestibular nucleus. 11. Nucleus ambiguus (nucleus of origin of motor fibres of glossopharyngeal, vagus, and cerebral portion of accessory). 12. Nucleus gracilis. 13. Nucleus cuneatus. 14. Nucleus of trigeminal nerve, with 14′, the spinal root of trigeminal nerve. 15. Fasciculus solitarius. 16. External arcuate fibres, with 16′, the nucleus arcuatus. 17. Nucleus lateralis. 19. Ligula.

the upturned end of the posterior ramus, and the *temporal* below the posterior ramus. The frontal operculum is of small size in those cases where the anterior horizontal and ascending rami of the lateral fissure arise from a common stem. When the opercula have been removed, the insula is seen as a pyramidal eminence, the apex of which is directed towards the anterior perforated substance. It is divided into a larger anterior and a smaller posterior part by a deep sulcus (sulcus centralis insulæ) which runs backwards and upwards from the apex of the insula. The anterior part is subdivided by shallow sulci into three or four *short gyri*, while the posterior part is formed by one *long gyrus*, which is often divided at its upper end. The cortical grey substance of the insula is continuous with that of the different opercula, while its deep surface corresponds with the lentiform nucleus of the corpus striatum.

FIG. 845.—The insula of the left side. Exposed by removing the opercula.



The **limbic lobe** (fig. 842).—The term limbic lobe was introduced by Broca, and under it he included the cingulate and hippocampal gyri, which together arch round the corpus callosum and the hippocampal fissure. These he separated on the morphological ground that they are well developed in animals possessing a keen sense of smell (osmatic animals), such as the dog and fox.

The *cingulate gyrus* is an arched convolution, lying in close relation to the superficial surface of the corpus callosum, from which it is separated by a slit-like fissure, the *callosal fissure*. It commences below the rostrum of the corpus callosum, curves round in front of its genu, extends along the upper surface of its body, and finally turns downwards behind the splenium, where it is connected by a narrow *isthmus* with the hippocampal gyrus. It is separated from the medial part of the superior frontal gyrus by the cingulate sulcus, and from the præcuneus by the subparietal sulcus.

The **callosal fissure** separates the cingulate gyrus from the convex surface of the corpus callosum, and, curving round the splenium, is continuous with the hippocampal fissure.

The *hippocampal gyrus* is bounded above by the hippocampal fissure, and below by the anterior part of the collateral fissure. Behind, it is continuous superiorly, through the isthmus, with the cingulate gyrus and inferiorly with the lingual gyrus. Running in the substance of the cingulate and hippocampal gyri, and connecting them together, is a tract of arched fibres, named the *cingulum* (p. 866). The anterior extremity of the hippocampal gyrus is recurved in the form of a hook (*uncus*), which is separated from the apex of the temporal lobe by a slight fissure, the *incisura temporalis*. Although superficially continuous with the hippocampal gyrus, the uncus forms morphologically a part of the rhinencephalon.

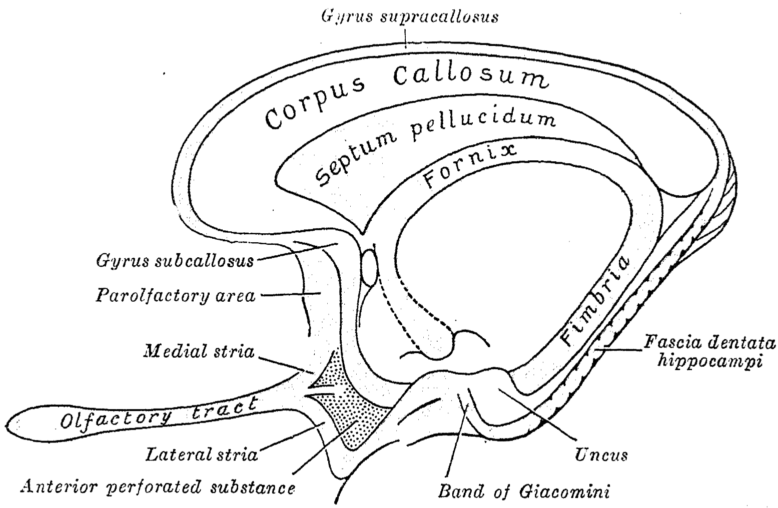
The **hippocampal fissure** begins immediately behind the splenium of the corpus callosum, and runs forwards between the hippocampal and dentate gyri to end in the uncus. It gives rise to the prominence of the hippocampus in the inferior cornu of the lateral ventricle.

The Rhinencephalon

The **rhinencephalon** (fig. 846) comprises the olfactory lobe, the uncus, the subcallosal and supracallosal gyri, the fascia dentata hippocampi, the septum pellucidum, the fornix, and the hippocampus.

1. The **olfactory lobe** is situated under the inferior or orbital surface of the frontal lobe. In many vertebrates it constitutes a well-marked portion

Fig. 846.—A scheme of the rhinencephalon.



of the hemisphere and contains an extension of the lateral ventricle; but in man and some other mammals it is rudimentary. It consists of the olfactory bulb and tract, the olfactory trigone, the parolfactory area of Broca, and the anterior perforated substance.

(*a*) The *olfactory bulb* is an oval, reddish-grey mass which lies above the lamina cribrosa of the ethmoidal bone, and forms the anterior expanded extremity of the olfactory tract. The olfactory nerves pass upwards through the lamina cribrosa from the olfactory region of the nasal cavity and enter the inferior surface of the olfactory bulb. Its minute structure is described on p. 872. The two olfactory bulbs are connected by fibres which run backwards in the olfactory tracts and decussate in the anterior commissure.

(*b*) The *olfactory tract* is a narrow white band, triangular on coronal section, the apex being directed upwards. It lies in the olfactory sulcus on the inferior surface of the frontal lobe, and divides posteriorly into two striæ, a medial and a lateral. The *lateral stria* is directed across the lateral part of the anterior perforated substance and then bends abruptly medialwards towards the uncus of the hippocampal gyrus. The *medial stria* turns medialwards behind the parolfactory area and ends in the subcallosal gyrus; in some cases a small *intermediate stria* is seen running backwards to the anterior perforated substance.

(*c*) The *olfactory trigone* is a small pyramidal area at the posterior end of the olfactory tract, and in front of the anterior perforated substance. Its apex, directed forwards, occupies the posterior part of the olfactory sulcus, and is brought into view by throwing back the olfactory tract.

(*d*) The *parolfactory area of Broca* is a small triangular field on the medial surface of the hemisphere in front of the subcallosal gyrus, from which it is separated by the posterior parolfactory sulcus; it is continuous below with the olfactory trigone, and above and in front with the cingulate gyrus; it is limited anteriorly by the *anterior parolfactory sulcus*.

(*e*) The *anterior perforated substance* is an irregularly quadrilateral area in front of the optic tract and behind the olfactory trigone, from which it is separated by the *fissura prima*; medially and in front it is continuous with the subcallosal gyrus; laterally it is bounded by the lateral stria of the olfactory tract and is continued into the uncus. Its grey substance is confluent above with that of the corpus striatum, and is perforated anteriorly by numerous small blood-vessels.

2. The **uncus** has already been described (p. 850) as the recurved, hook-like portion of the hippocampal gyrus.

3. The **subcallosal and supracallosal gyri** and the **fascia dentata hippocampi** form a rudimentary arch-shaped lamina of grey substance, extending over the corpus callosum and above the hippocampal gyrus, from the anterior perforated substance to the uncus.

(*a*) The *subcallosal gyrus* (peduncle of the corpus callosum) is a narrow lamina on the medial surface of the hemisphere, in front of the lamina terminalis, behind the parolfactory area, and below the rostrum of the corpus callosum. It is continuous above around the genu of the corpus callosum with the supracallosal gyrus; below, it may be traced along the side of the optic tract as a white band, the *diagonal band of Broca*, to the anterior end of the gyrus hippocampi.

(*b*) The *supracallosal gyrus* or *indusium griseum* consists of a thin layer of grey substance in contact with the upper surface of the corpus callosum and continuous laterally with the grey substance of the cingulate gyrus. It contains two longitudinally directed strands of fibres termed the *medial* and *lateral longitudinal striæ*. The supracallosal gyrus is prolonged round the splenium of the corpus callosum as a delicate lamina, the *fasciola cinerea*, which is continuous below with the fascia dentata hippocampi.

(*c*) The *fascia dentata hippocampi* (dentate gyrus) is a narrow band extending downwards and forwards above the hippocampal gyrus but separated from it by the hippocampal fissure; its free margin is notched, and is overlapped by the fimbria—the *fimbriodentate fissure* intervening. Anteriorly it is continued into the notch of the uncus, where it bends sharply and is then prolonged as a delicate band, the *band of Giacomini*, over the uncus, on the lateral surface of which it is lost.

The remaining parts of the rhinencephalon, viz. the septum pellucidum, the fornix, and the hippocampus, will be described in connexion with the lateral ventricle.

The Interior of the Cerebral Hemispheres

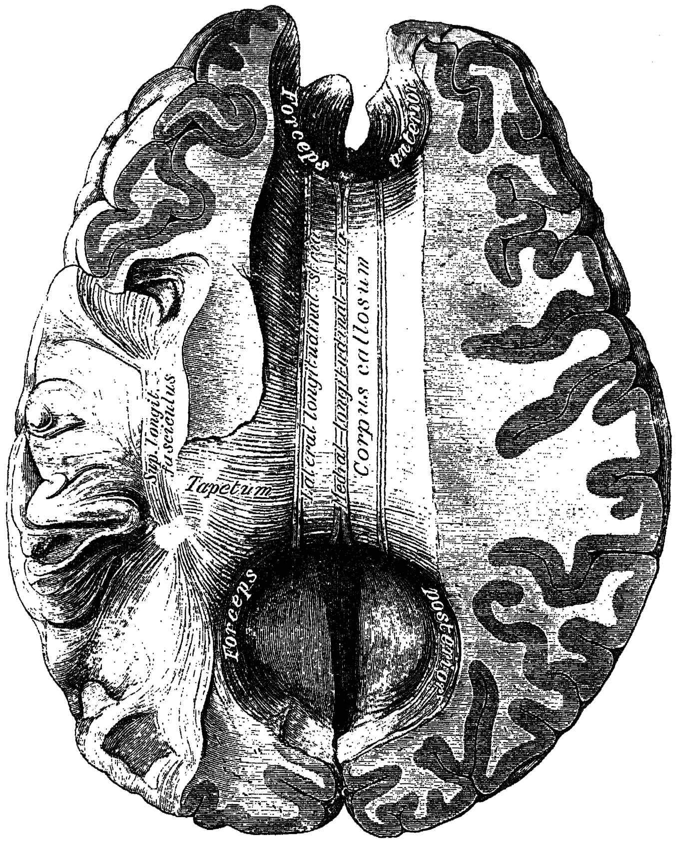
If the upper part of either hemisphere be removed, at a level about 1·25 cm. above the corpus callosum, the central white substance will be exposed as an oval-shaped area, the *centrum ovale minus*, surrounded by a narrow convoluted margin of grey substance, and studded with numerous minute red dots (*puncta vasculosa*) produced by the escape of blood from divided blood-vessels. If the remaining portions of the hemispheres be drawn slightly apart a broad band of white substance, the *corpus callosum*, will be observed, connecting them at the bottom of the longitudinal fissure; the margins of the hemispheres which overlap the corpus callosum are called the *labia cerebri*. Each labium is part of the cingulate gyrus already described (p. 850); and the slit-like interval between it and the upper surface of the corpus callosum is termed the *callosal fissure*. If the hemispheres be sliced off until level with the upper surface of the corpus callosum, the white substance of that structure will be seen connecting them.* The large expanse of medullary matter now exposed, surrounded by the convoluted margin of grey substance, is called the *centrum ovale majus*.

* A better view of the corpus callosum, and of the way in which its fibres pass into the hemisphere, is obtained by inserting the fingers into the callosal fissure and tearing off the cingulate gyrus in a lateral direction.

The **corpus callosum** (fig. 847) is the great transverse commissure which unites the cerebral hemispheres and roofs in the lateral ventricles. A good conception of its position and size is obtained by examining a median sagittal section of the brain (fig. 833), when it is seen to form an arched structure about 10 cm. long. Its anterior end is about 4 cm. from the frontal pole, and its posterior end about 6 cm. from the occipital pole, of the hemisphere.

The *anterior end* is named the *genu*, and is bent downwards and backwards in front of the septum pellucidum; diminishing rapidly in thickness, it is prolonged backwards, under the name of the *rostrum*, which is connected below

Fig. 847.—The corpus callosum. Exposed from above.



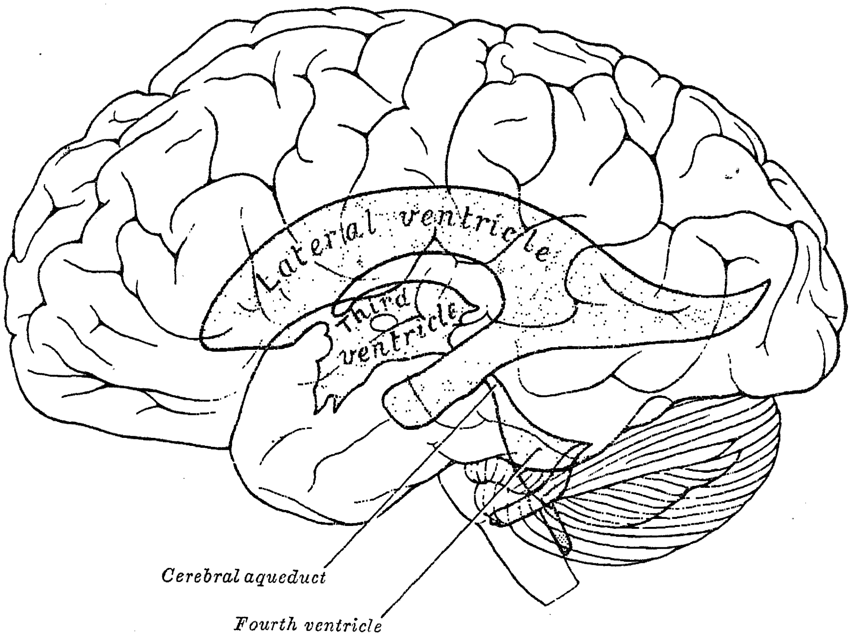
with the lamina terminalis. The anterior cerebral arteries are in contact with the under surface of the rostrum; they then arch over the front of the genu, and are carried backwards above the body of the corpus callosum.

The *posterior end* is named the *splenium*, and constitutes the thickest part of the corpus callosum. It overlaps the tela chorioidea of the third ventricle and the mesencephalon, and ends in a thick, convex free border. A sagittal section of the splenium shows that the posterior end of the corpus callosum is acutely bent forwards, the upper and lower parts being applied to each other.

The *superior surface* is convex from before backwards, and is about 2·5 cm. wide. Its median part forms the bottom of the longitudinal fissure, and is in contact posteriorly with the lower border of the falx cerebri. On either side the superior surface is overlapped by the cingulate gyrus, but is separated from it by the slit-like callosal fissure. It is traversed by numerous transverse ridges and furrows, and is covered by a thin layer of grey matter, the supracallosal gyrus, which exhibits on either side of the middle line the medial and lateral longitudinal striæ already described (p. 852).

The *inferior surface* is concave, and forms on either side of the middle line the roof of the lateral ventricle. The median part of the surface is attached in

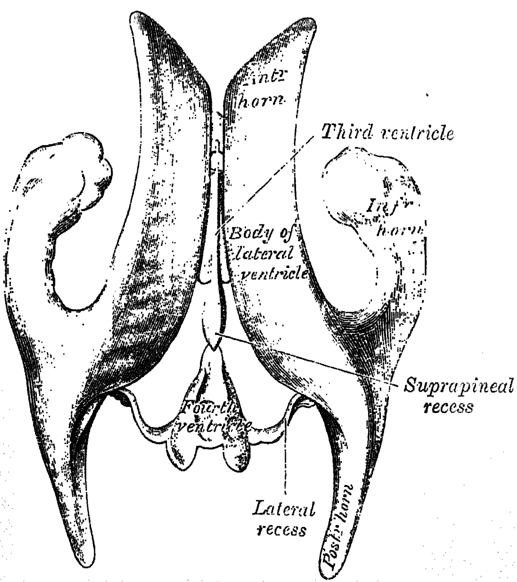
FIG. 848.—A scheme showing the relations of the ventricles to the surface of the brain.



front to the septum pellucidum ; behind this it is fused with the upper surface of the body of the fornix.

On either side, the fibres of the corpus callosum radiate in the white substance and pass to the various parts of the cerebral cortex ; those curving forward from the genu into the frontal lobes constitute the *forceps anterior*, and those curving backwards from the splenium into the occipital lobes, the *forceps posterior*. Between these two parts is the *tapetum* constituting the main body of the fibres ; these run laterally into the temporal and parietal lobes, and cover the central part of the lateral ventricle.

FIG. 849.—A drawing of a cast of the ventricular cavities. Superior aspect. (Retzius.)



The **lateral ventricles** (fig. 848).—The two lateral ventricles are irregular cavities situated in the lower and medial parts of the cerebral hemispheres, one on either side of the middle line. They are separated from each other by a median vertical partition, the *septum pellucidum*, but communicate with the third ventricle and indirectly with each other through the *interventricular foramen*. They are lined by a thin, diaphanous

FIG. 850.—A drawing of a cast of the ventricular cavities. Right lateral aspect. (Retzius.)

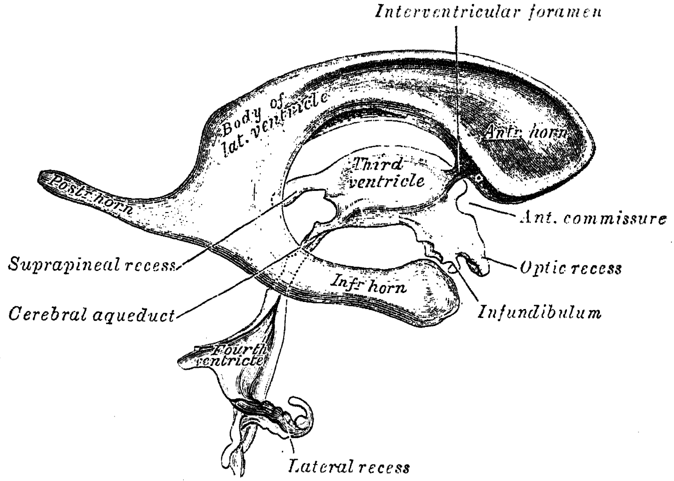
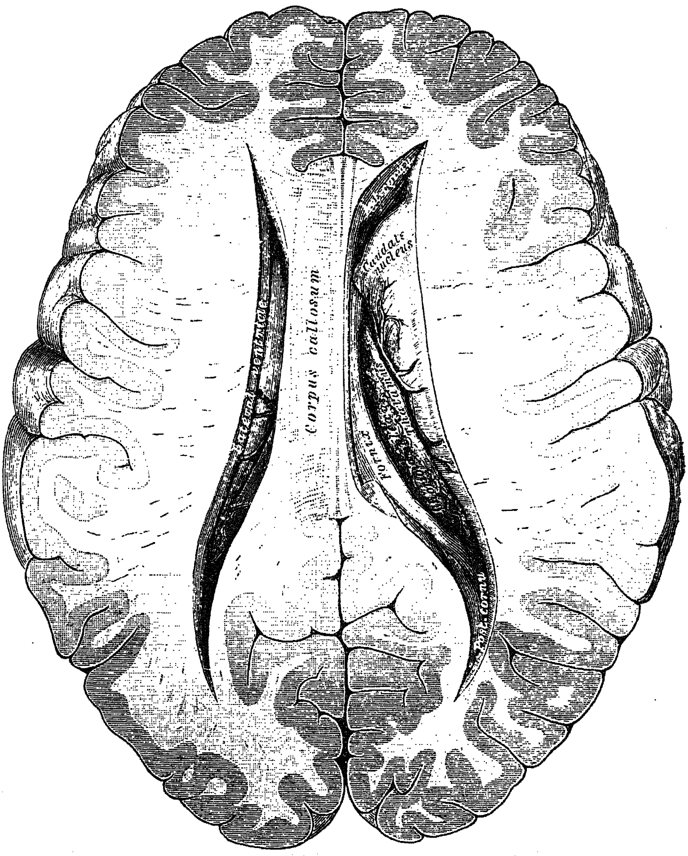


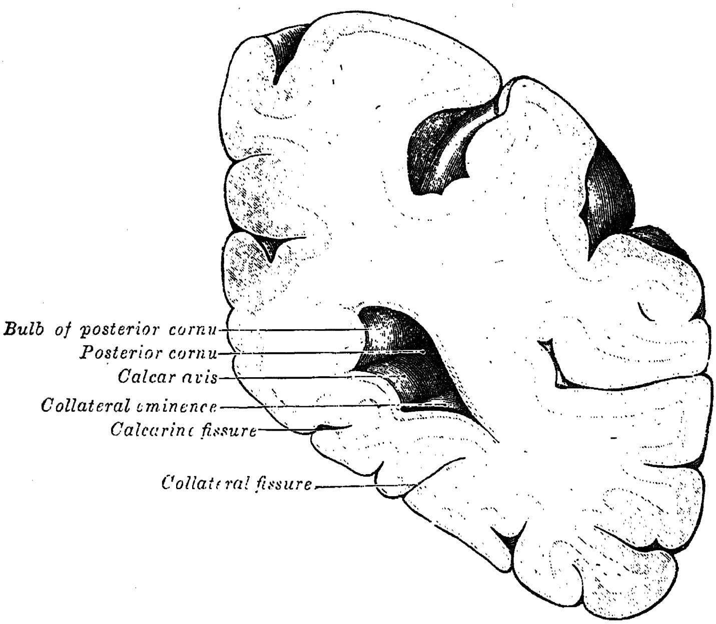
FIG. 851.—The central parts and the anterior and posterior cornua of the lateral ventricles. Exposed from above.



membrane, covered by ciliated epithelium and termed the *ependyma*, and they contain cerebrospinal fluid, which, even in health, may be secreted in considerable amount. Each lateral ventricle consists of a *central part or body*, and three *cornua*, an anterior, a posterior, and an inferior (figs. 849, 850).

The **central part** (fig. 851) of the lateral ventricle extends from the interventricular foramen to the splenium of the corpus callosum. It is an irregularly curved cavity, triangular on transverse section, with a roof, a floor, and a medial wall. The roof is formed by the under surface of the corpus callosum; the floor, directed upwards and medialwards, by the following parts, named in their order of position from before backwards: the caudate nucleus of the corpus striatum, the stria terminalis and the terminal vein (vein of corpus striatum), the lateral portion of the upper surface of the

Fig. 852.—A coronal section through the posterior cornu of the left lateral ventricle. Anterior aspect.



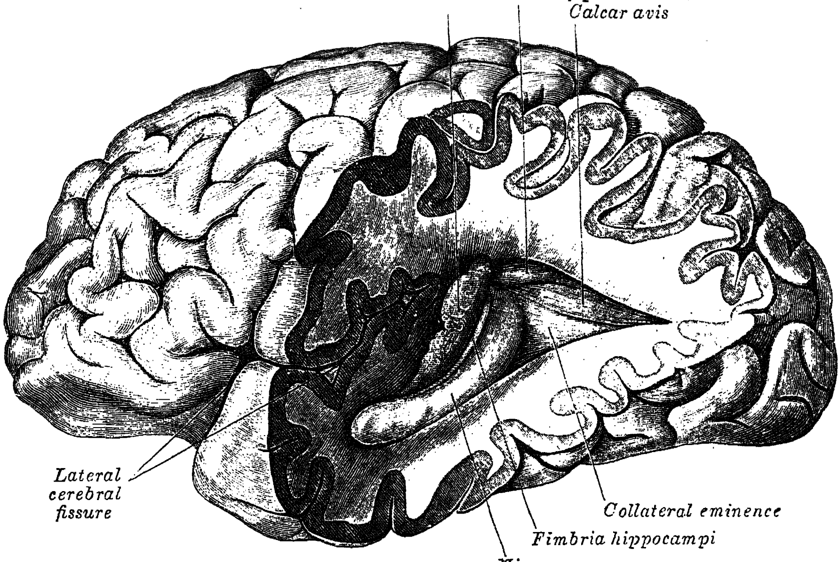
thalamus, the chorioid plexus, and the lateral part of the fornix; the medial wall is the posterior part of the septum pellucidum, which separates the ventricle from that of the opposite side.

The **anterior cornu** (fig. 851) passes forwards, lateralwards and slightly downwards, into the frontal lobe, curving round a large swelling which consists of the head or anterior end of the caudate nucleus. In a coronal section it appears as a triangular slit below the anterior part of the corpus callosum, and bounded anteriorly by the posterior surface of the genu of the corpus callosum. Its floor is convex, directed upwards and medialwards, and is formed by the head of the caudate nucleus. Its medial wall is the septum pellucidum (p. 864).

The **posterior cornu** (figs. 851, 852) passes into the occipital lobe, its direction being backwards and lateralwards, and then medialwards. Its roof and lateral wall are formed by the fibres of the corpus callosum passing to the temporal and occipital lobes. On its medial wall is a longitudinal eminence, the *calcar avis*, which is an involution of the ventricular wall produced by the anterior part of the calcarine fissure. Above this the forceps posterior of the corpus callosum, sweeping round to enter the occipital lobe, causes another projection, termed the *bulb* of the posterior cornu. The calcar avis and bulb of the posterior cornu are very variable in their degree of development; in some cases they are ill-defined, in others prominent.

The **inferior cornu** (fig. 853), the largest of the three, traverses the temporal lobe, forming in its course a curve round the posterior end of the thalamus. It passes at first backwards, lateralwards, and downwards, and then curves forwards to within 2·5 cm. of the apex of the temporal lobe, its position being fairly well indicated on the surface of the brain by the superior temporal sulcus. Its roof is formed chiefly by the inferior surface of the tapetum of the corpus callosum, but the tail of the caudate nucleus and the stria terminalis also extend forwards in the roof, at the extremity of which they end in a mass of grey substance, the *nucleus amygdalæ.* Its floor presents the following parts: the chorioid plexus, the fimbria hippocampi, the hippocampus and the collateral eminence. When the chorioid plexus is removed, a cleft-like opening is left along the medial wall of the inferior cornu; this cleft constitutes the lower part of the chorioidal fissure.

FIG. 853.—The posterior and inferior cornua of the left lateral ventricle. Exposed from the side.



The chorioid plexus is described on p. 864, and the fimbria hippocampi on p. 863.

The **hippocampus** (figs. 853, 854) is a curved eminence, about 5 cm. long, which extends throughout the entire length of the floor of the inferior cornu. Its lower end is enlarged, and presents two or three rounded elevations or digitations, which give it a paw-like appearance, and hence it is named the *pes hippocampi.* It is separated from the hippocampal gyrus by a shallow groove, the hippocampal fissure. The main mass of the hippocampus consists of grey substance; but on its ventricular surface is a thin white layer, the *alveus,* which is continuous with the fimbria hippocampi.

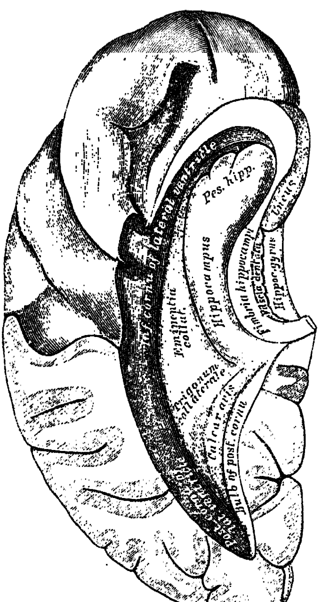
The **collateral eminence** (fig. 854) is an elongated swelling lying lateral to and parallel with the hippocampus. It corresponds with the middle part of the collateral fissure, and its size depends on the depth and direction of this fissure. It is continuous behind with a flattened triangular area, the *trigonum collaterale,* situated between the posterior and inferior cornua.

The **corpus striatum** has received its name from the striped appearance which a section of its anterior part presents, in consequence of diverging white fibres being mixed with the grey substance which forms its chief mass. A part of the corpus striatum is imbedded in the white substance of the cerebral hemisphere, and is therefore external to the ventricle; it is termed the

extraventricular portion, or the *lentiform nucleus*; the remainder, however, projects into the ventricle, and is named the *intraventricular portion*, or the *caudate nucleus* (fig. 855).

The **caudate nucleus** (fig. 851) is a pear-shaped, highly arched grey mass; its broad extremity, or *head*, is directed forwards into the anterior cornu of the lateral ventricle, and is continuous with the anterior perforated substance and with the anterior end of the lentiform nucleus; its narrow end, or *tail*, is directed backwards on the lateral side of the thalamus, from which it is separated by the stria terminalis and the terminal vein; it is then continued downwards into the roof of the inferior cornu, and ends in the *nucleus amygdalæ*. It is covered by the ependyma of the lateral ventricle, and crossed by some veins of considerable size. It is separated from the lentiform nucleus, in the greater part of its extent, by a thick lamina of white substance, called the *internal capsule*, but the two nuclei are united in front (figs. 856, 857).

Fig. 854.—The posterior and inferior cornua of the left lateral ventricle. Exposed from above.



The **lentiform nucleus** (lenticular nucleus) is lateral to the caudate nucleus and thalamus, and is seen only in sections of the hemisphere. When divided horizontally, it exhibits, to some extent, the appearance of a biconvex lens (fig. 855), while a coronal section of its central part presents a somewhat triangular outline. It is shorter than the caudate nucleus and does not extend as far forwards. It is bounded medially by the internal capsule, and laterally by a lamina of white substance called the *external capsule*; lateral to this is a thin layer of grey substance termed the *claustrum*, which separates it from the insula. Its anterior end is continuous with the lower part of the head of the caudate nucleus and with the anterior perforated substance.

In a coronal section through the middle of the lentiform nucleus (fig. 857) two *medullary laminæ* are seen dividing it into three parts. The lateral and largest part is of a reddish colour, and is known as the *putamen*, while the medial and intermediate parts are of a yellowish tint, and together constitute the *globus pallidus*; all three are marked by fine radiating white fibres, which are most distinct in the putamen.

The grey substance of the corpus striatum is traversed by nerve-fibres, some of which originate in it. The cells are multipolar, both large and small; those of the lentiform nucleus contain yellow pigment. The caudate and lentiform nuclei are not only directly continuous with each other anteriorly, but are connected to each other by numerous fibres. The corpus striatum is also connected: (1) to the cerebral cortex, by the *corticostriate* fibres; (2) to the thalamus, by fibres which pass through the internal capsule, and by a strand named the *ansa lentiformis* (p. 860); (3) to the cerebral peduncle, by fibres which leave the lower parts of the caudate and lentiform nuclei.

The **claustrum** (figs. 855, 857) is a thin layer of grey substance, situated on the lateral surface of the external capsule. In a coronal section it is seen to be triangular in shape, with the apex directed upwards. Its medial surface, contiguous to the external capsule, is smooth, but its lateral surface presents ridges and furrows corresponding with the gyri and sulci of the insula, with which it is in close relationship. The claustrum is regarded by some as a detached portion of the grey substance of the insula, from which it is separated by a layer of white fibres, the *capsula extrema*. Its cells are small and spindle-shaped and contain yellow pigment; they are similar to those of the deepest layer of the cortex.*

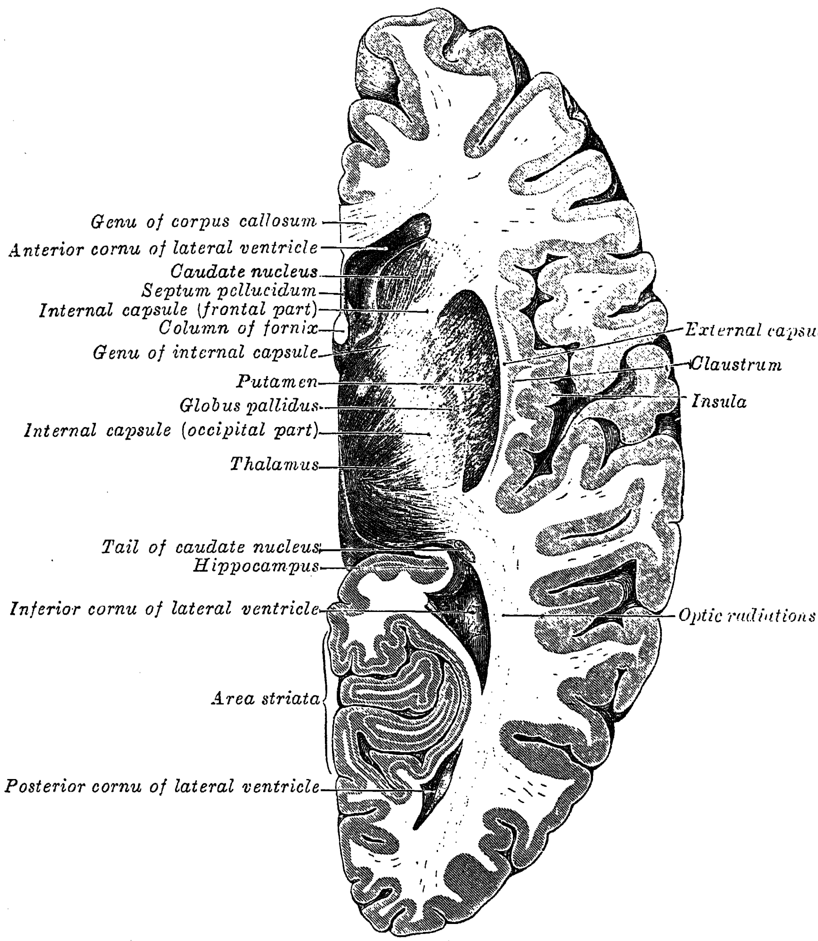
* E. Landau (*Journal of Anatomy*, vol. liii.) is of opinion that the claustrum is an independent formation which is neither split off from the cortex of the insula nor from the corpus striatum.

The **nucleus amygdalæ** is an ovoid grey mass, situated above and in front of the lower end of the inferior cornu. It is merely a localised thickening of the grey cortex, confluent with that of the uncus; above, it is continuous with the putamen; behind. with the tail of the caudate nucleus.

The caudate, lentiform and amygdaloid nuclei are sometimes grouped under the term *basal ganglia*.

The **internal capsule** (figs. 855. 857) is a flattened band of white fibres, between the lentiform nucleus on the lateral side and the caudate nucleus and

Fig. 855.—A horizontal section through the right cerebral hemisphere. Superior aspect.

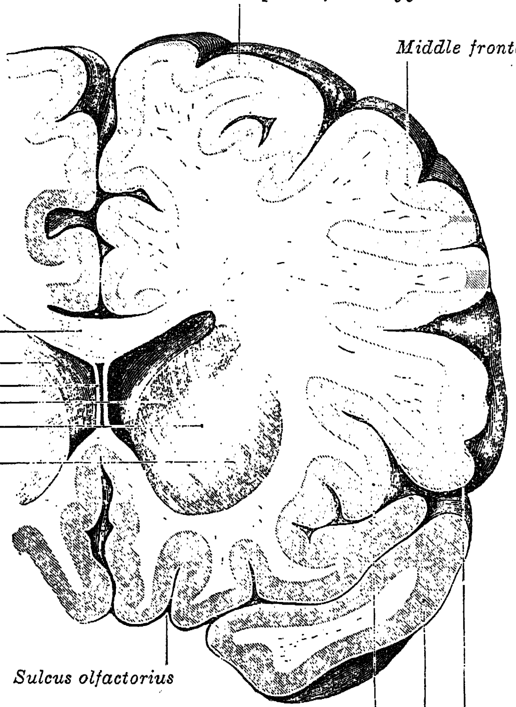


thalamus on the medial side. In horizontal section (fig. 855), it is seen to be somewhat abruptly curved, with its convexity directed medialwards; the prominence of the curve, the *genu*, projects between the caudate nucleus and the thalamus. The portion in front of the genu, separating the lentiform and caudate nuclei, is termed the frontal part; the portion behind the genu, separating the lentiform nucleus from the thalamus, is the occipital part.

The *frontal part* (anterior limb) of the internal capsule contains: (1) fibres running from the thalamus, as its anterior stalk, to the frontal lobe; (2) fibres joining the lentiform and caudate nuclei; (3) fibres connecting the cortex with the corpus striatum; and (4) fibres (frontopontine tract) passing from the frontal lobe through the medial one-fifth of the base of the cerebral peduncle to the nuclei pontis. The fibres in the region of the genu are named the *geniculate fibres*; they originate in the motor part of the cerebral cortex,

and, after passing downwards through the base of the cerebral peduncle with the cerebrospinal fibres, undergo decussation and end in the motor nuclei of the cerebral nerves of the opposite side. The anterior two-thirds of the occipital part of the internal capsule contains the *cerebrospinal fibres*, which arise in the motor area of the cerebral cortex, and passing downwards through the middle three-fifths of the base of the cerebral peduncle, are continued into the pyramids of the medulla oblongata. The posterior one-third of the occipital part (posterior l mb) contains: (1) sensory fibres, largely derived from the thalamus, though some may be continued upwards from the medial lemniscus; (2) the fibres of the optic radiations, from the lateral geniculate body and

Fig. 856.—A coronal section through the anterior cornua of the lateral ventricles. Anterior aspect.



pulvinar to the cortex of the occipital lobe; (3) acoustic fibres, from the medial geniculate body and inferior colliculus to the gyri of Heschl in the temporal lobe; (4) fibres which pass from the occipital and temporal lobes to the nuclei pontis; and (5) fibres from the occipital cortex to the superior colliculus.

The fibres of the internal capsule radiate widely as they pass to and from the various parts of the cerebral cortex, forming the *corona radiata* (fig. 858) and intermingling with the fibres of the corpus callosum.

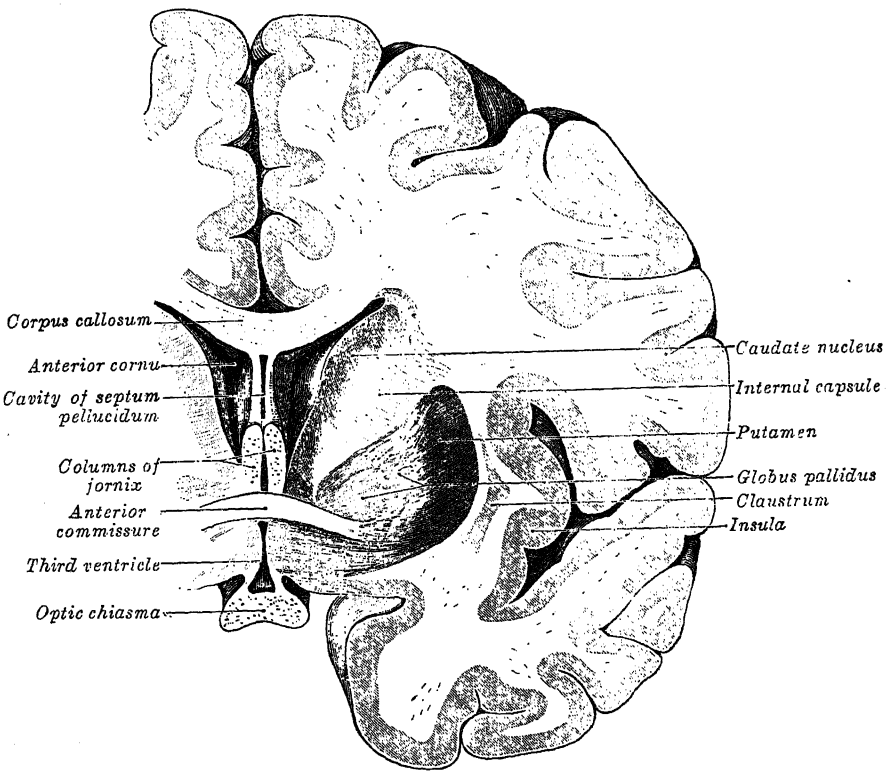
The external capsule (fig. 855) is a lamina of white substance, situated lateral to the lentiform nucleus, between it and the claustrum, and continuous with the internal capsule, below and behind the lentiform nucleus. It probably contains fibres derived from the thalamus, the anterior commissure, and the subthalamic region.

The substantia innominata of Meynert is a stratum consisting of grey and white substance, which lies below the anterior parts of the thalamus and lentiform nucleus. It consists of three layers, superior, middle, and inferior. The *superior* layer is named the *ansa lentiformis*, and its fibres, derived from

the medullary laminæ of the lentiform nucleus, pass medially to end in the thalamus and subthalamic region, while others are said to end in the tegmentum and red nucleus. The *middle* layer consists of nerve-cells and nerve-fibres: fibres enter it from the parietal lobe through the external capsule, while others are said to connect it with the medial longitudinal fasciculus. The *inferior* layer forms the main part of the inferior stalk of the thalamus, and connects this body with the temporal lobe and the insula.

The **stria terminalis** (tænia semicircularis) is a narrow band of white substance situated in the floor of the lateral ventricle between the caudate nucleus and the thalamus. Anteriorly, its fibres are partly continued into

Fig. 857.—A coronal section through the brain, passing through the anterior commissure. Anterior aspect.

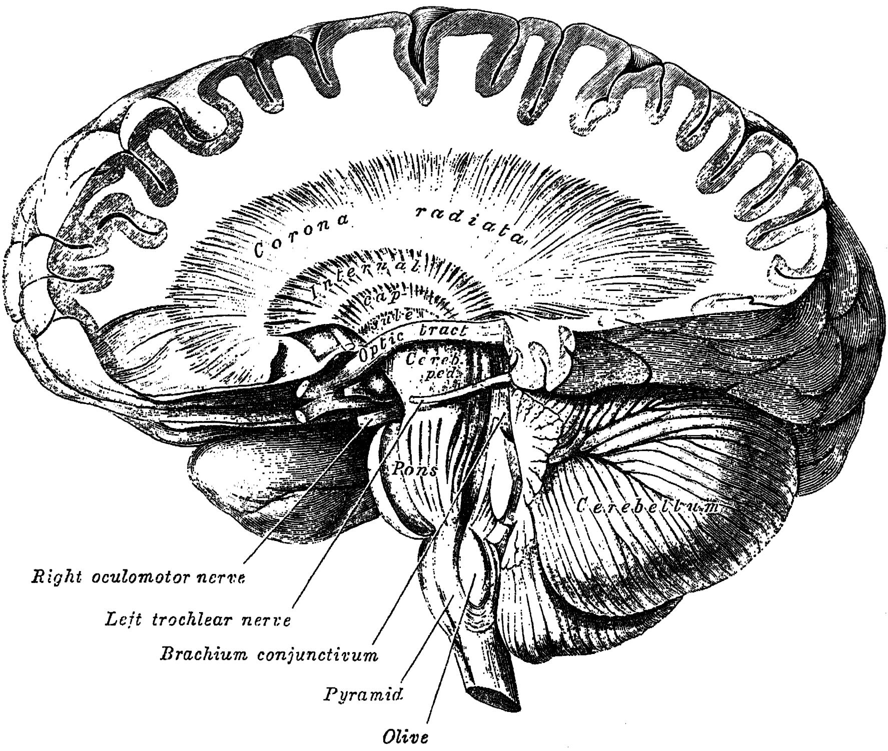


the column of the fornix; some cross in the anterior commissure to the temporal lobe of the opposite side; others are said to enter the caudate nucleus. Posteriorly, it is continued into the roof of the inferior cornu of the lateral ventricle, at the extremity of which it enters the nucleus amygdalæ. Superficial to it is the terminal vein (vein of the corpus striatum), which receives numerous tributaries from the corpus striatum and thalamus; it runs forwards to the interventricular foramen and there joins with the vein of the chorioid plexus to form the corresponding internal cerebral vein. On the surface of the terminal vein is a narrow white band, named the *lamina affixa*.

The **fornix** (figs. 833, 859) is a longitudinal, arch-shaped lamella of white substance, situated below the corpus callosum, and attached to its inferior surface behind, but separated from it in front by the septum pellucidum. It may be described as consisting of two symmetrical bands, one for either hemisphere. The two bands are not united to each other in front and behind, but their central parts are joined together in the middle line. The anterior parts are called the columns of the fornix; the intermediate united portions, the body; and the posterior parts, the crura.

The *body* of the fornix is triangular, narrow in front, and broad behind. The medial part of its upper surface is connected to the septum pellucidum in front and to the corpus callosum behind. The lateral portion of this surface forms part of the floor of the lateral ventricle, and is covered by the ventricular epithelium. Its thin lateral edge overlaps the chorioid plexus, and is continuous with the epithelial covering of the plexus. The under surface rests upon the tela chorioidea of the third ventricle (velum interpositum), which separates it from the epithelial roof of the third ventricle, and from the medial portions of the upper surfaces of the thalami. The lateral portions of the body of the fornix are joined inferiorly by a thin triangular lamina, named the *psalterium or lyra*. This lamina contains some transverse fibres

FIG. 858.—A dissection showing the course of the cerebrospinal fibres. (E. B. Jamieson.)



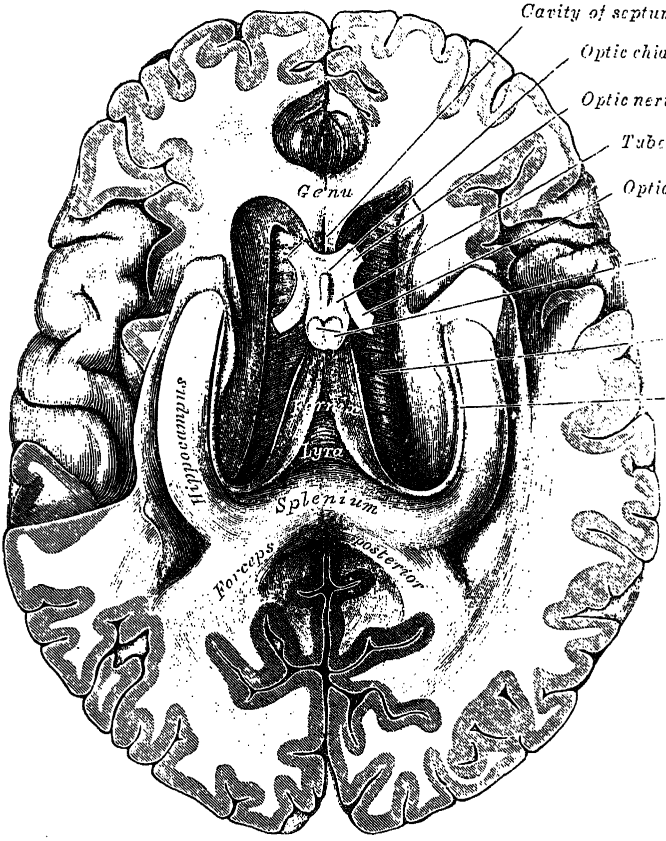
which connect the two hippocampi across the middle line and constitute the *hippocampal commissure*. Between the psalterium and the corpus callosum a horizontal cleft, the so-called *ventricle of the fornix or ventricle of Verga*, is sometimes found.

The *columns* (anterior pillars) of the fornix arch downwards in front of the thalamus and behind the anterior commissure, and form the anterior boundary of the interventricular foramen; each descends through the grey substance in the lateral wall of the third ventricle to the base of the brain, where it ends mainly in the corpus mamillare. From the cells of the corpus mamillare the *mamillothalamic fasciculus* (bundle of Vicq d'Azyr) takes origin and is prolonged into the anterior nucleus of the thalamus. The column of the fornix and the mamillothalamic fasciculus together form a loop resembling the figure 8, but the continuity of the loop is broken in the corpus mamillare. The column of the fornix is joined by the stria medullaris of the pineal body and by the superficial fibres of the stria terminalis; it is said also to receive fibres from the septum pellucidum. Zuckerkandl describes an *olfactory fasciculus* which becomes detached from the main portion of the column of the fornix,

and passes downwards in front of the anterior commissure to the base of the brain, where it divides into two bundles; one joins the medial stria of the olfactory tract; the other joins the subcallosal gyrus, and through it reaches the hippocampal gyrus.

The *crura* (posterior pillars) of the fornix are prolonged backwards from the body. They are flattened bands, and at their commencement are intimately connected with the under surface of the corpus callosum. Diverging from one another, each curves round the posterior end of the thalamus, and passes

Fig. 859.—The fornix and the corpus callosum. Exposed from below. (From a specimen in the Department of Human Anatomy of the University of Oxford.)



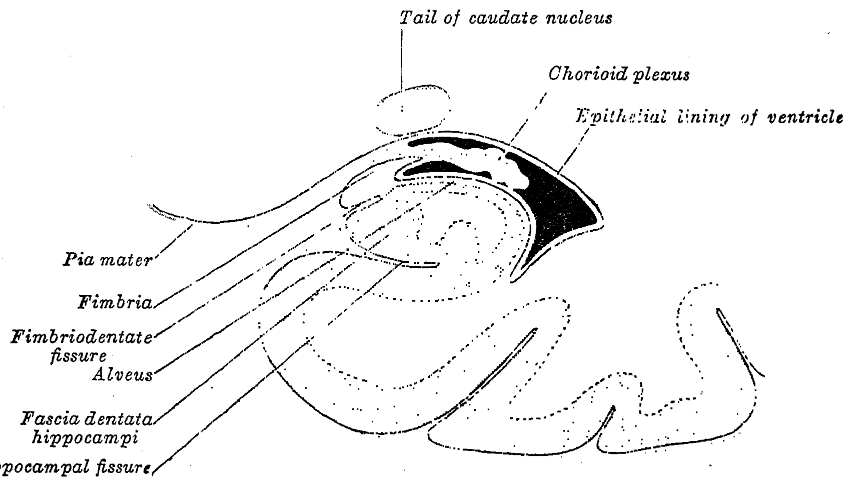
downwards and forwards into the inferior cornu of the lateral ventricle (figs. 854, 859). Here it lies along the concavity of the hippocampus, on the surface of which some of its fibres are spread out to form the *alveus*, while the remainder are continued as a narrow white band, the *fimbria hippocampi*, which is prolonged into the uncus of the hippocampal gyrus. The medial edge of the fimbria overlaps the fascia dentata hippocampi (dentate gyrus) (p. 852), from which it is separated by the *fimbriodentate fissure*; from its lateral, thin edge the ventricular epithelium is reflected over the chorioid plexus as the latter projects into the chorioidal fissure.

The **interventricular foramen** (foramen of Monro).—There is an aperture between the columns of the fornix and the anterior ends of the thalami: this is the interventricular foramen, and through it the lateral ventricles communicate with the third ventricle. Behind the epithelial lining of the foramen the chorioid plexuses of the lateral ventricles are joined across the middle line.

The **anterior commissure** (fig. 857) is a bundle of white fibres which runs transversely between the two cerebral hemispheres, and is placed in front of the columns of the fornix. On sagittal section it is oval in shape, its long diameter being vertical and measuring about 5 mm. Its fibres can be traced lateralwards and backwards on either side beneath the corpus striatum into the substance of the temporal lobe. It connects the two temporal lobes, and also contains decussating fibres from the olfactory bulbs.

The **septum pellucidum** (fig. 833) is a thin, vertical partition consisting of two laminæ, separated in the greater part of their extent by a narrow chink or interval, the *cavity of the septum pellucidum*. It is triangular in form, with its base in front; its inferior angle corresponds with the upper part of the anterior commissure. It is attached, above, to the under surface of the corpus callosum; below and behind, to the anterior part of the fornix: below and in front, to the reflected portion of the corpus callosum. The lateral surface of each lamina is directed towards the body and anterior cornu of the lateral ventricle, and is covered by the ependyma of that cavity.

FIG. 860.—A coronal section through the inferior cornu of the lateral ventricle. Diagrammatic.

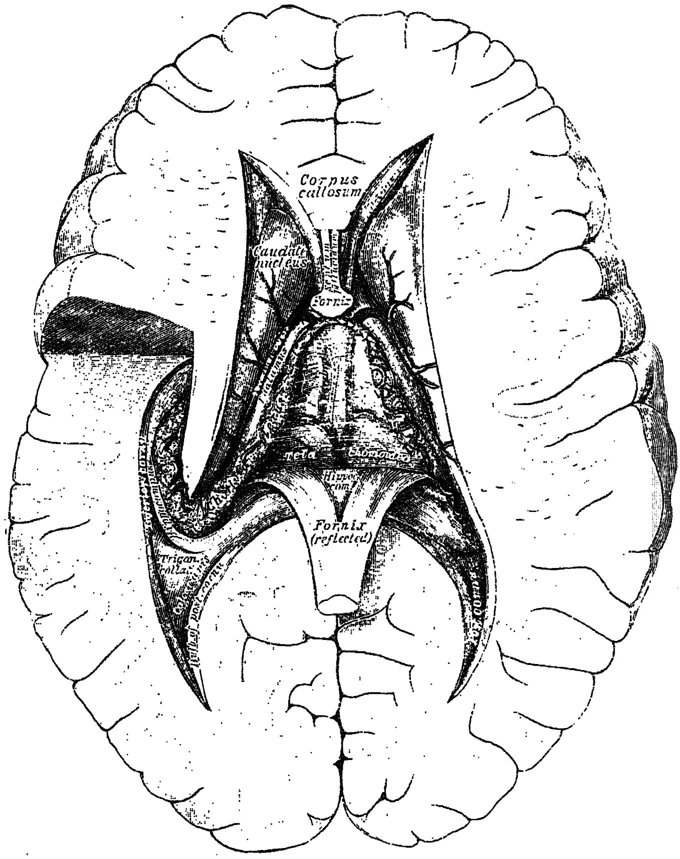


The *cavity of the septum pellucidum* is generally believed to be a part of the longitudinal cerebral fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below. Each half of the septum therefore forms part of the medial wall of the hemisphere, and consists of a medial layer of grey substance derived from that of the cortex, and a lateral layer of white substance continuous with that of the cerebral hemispheres. This cavity is not developed from the cavity of the cerebral vesicles, and never communicates with the ventricles of the brain.

The **chorioid plexus of the lateral ventricle** (fig. 861) is a highly vascular, fringe-like process of pia mater which projects into the ventricular cavity, but is everywhere covered by a layer of epithelium continuous with the epithelial lining of the ventricle. It extends from the interventricular foramen, where it is joined with the plexus of the opposite ventricle, to the end of the inferior cornu. The part in relation to the body of the ventricle forms the vascular fringed margin of a triangular process of pia mater, named the tela chorioidea of the third ventricle, and projects from under cover of the lateral edge of the fornix. It lies upon the upper surface of the thalamus, from which the ventricular epithelium is reflected over the plexus on to the edge of the fornix (fig. 838). The portion in relation to the inferior cornu lies in the concavity of the hippocampus and overlaps the fimbria hippocampi; from the lateral edge of the fimbria the epithelium is reflected over the plexus on to the roof of the cornu (fig. 860).

The chorioid plexus consists of minute and highly vascular villous processes, each with an afferent and an efferent vessel. The *arteries* of the plexus are : (*a*) the anterior chorioidal, a branch of the internal carotid artery, which enters the plexus at the end of the inferior cornu ; and (*b*) the posterior chorioidal, one or two small branches of the posterior cerebral artery, which pass forwards under the splenium. The *veins* of the plexus unite to form a single tortuous vessel, which courses from behind forwards to the interventricular foramen and there joins with the terminal vein (p. 717) to form the corresponding internal cerebral vein.

FIG. 861.—The tela chorioidea of the third ventricle, and the chorioid plexus of the left lateral ventricle. Exposed from above.



When the chorioid plexus is pulled away, the continuity between its epithelial covering and the epithelial lining of the ventricle is severed, and a cleft-like space is produced. This is named the *chorioidal fissure* ; like the plexus, it extends from the interventricular foramen to the end of the inferior cornu. The upper part of the fissure, i.e. the part nearest the interventricular foramen, is situated between the lateral edge of the fornix and the upper surface of the thalamus ; farther back, at the beginning of the inferior cornu, it is between the commencement of the fimbria hippocampi and the posterior end of the thalamus, while in the inferior cornu it lies between the fimbria in the floor and the stria terminalis in the roof of the cornu.

The **tela chorioidea of the third ventricle** (velum interpositum) (fig. 861) is a double fold of pia mater, triangular in shape, which lies beneath the fornix. The lateral portions of its lower surface rest upon the thalami, while the medial portion of this surface is in contact with the epithelial roof

of the third ventricle. Its apex is situated at the interventricular foramen; its base occupies the interval between the splenium of the corpus callosum above and the corpora quadrigemina and pineal body below. This interval, together with the lower portions of the chorioidal fissures, is sometimes spoken of as the *transverse fissure* of the brain. The two layers of the tela separate from each other at the base, and are continuous with the pia mater investing the brain in this region. Its lateral margins are modified to form the highly vascular chorioid plexuses of the lateral ventricles. It is supplied by the anterior and posterior chorioidal arteries already described. The veins of the tela chorioidea are named the internal cerebral veins (venæ Galeni); they are two in number, and run backwards between its layers, each being formed at the interventricular foramen by the union of the terminal vein with the chorioidal vein. Beneath the splenium of the corpus callosum the internal cerebral veins unite to form the great cerebral vein (vena magna Galeni), which curves backwards and upwards behind the splenium and ends in the straight sinus.

The Structure of the Cerebral Hemispheres

The cerebral hemispheres are composed of white and grey substance.

The **white substance** occupies the interior of the hemispheres; it consists of medullated fibres which vary in size, and are supported by neuroglia. The fibres may be divided, according to their course and connexions, into three systems: projection fibres connecting the hemispheres with the lower parts of the brain and with the medulla spinalis; transverse or commissural fibres uniting the two hemispheres; association fibres connecting different structures in the same hemisphere; many of the last are collateral branches of the projection fibres, but some are the axons of independent cells.

1. The **projection fibres** consist of efferent and afferent fibres uniting the cortex with the lower parts of the brain and with the medulla spinalis. The principal efferent strands are: (1) the motor tract, occupying the genu and anterior two-thirds of the occipital part of the internal capsule, and consisting of (*a*) the geniculate fibres, which decussate and end in the motor nuclei of the cerebral nerves of the opposite side; and (*b*) the cerebrospinal fibres, which are prolonged through the pyramid of the medulla oblongata into the medulla spinalis; (2) the corticopontine fibres, ending in the nuclei pontis. The chief afferent fibres are: (1) those of the brachia conjunctiva cerebelli which are not interrupted in the red nucleus and thalamus; (2) numerous fibres arising within the thalamus, and passing through its stalks to the different parts of the cortex (p. 835); (3) optic and acoustic fibres, the former passing to the occipital, the latter to the temporal lobe.

2. The **transverse or commissural fibres** connect the two hemispheres. They include: (*a*) the transverse fibres of the corpus callosum, (*b*) the anterior commissure, (*c*) the posterior commissure, and (*d*) the lyra or hippocampal commissure; they have already been described.

3. The **association fibres** (fig. 862) unite different parts of the same hemisphere, and are of two kinds: (1) *short association fibres* connecting adjacent gyri; (2) *long association fibres* passing between more distant parts.

The *short association fibres* lie immediately beneath the grey substance of the cortex of the hemispheres, and connect adjacent gyri.

The *long association fibres* include the following: (*a*) the uncinate fasciculus; (*b*) the cingulum; (*c*) the superior longitudinal fasciculus; (*d*) the inferior longitudinal fasciculus; (*e*) the perpendicular fasciculus; (*f*) the occipitofrontal fasciculus; and (*g*) the fornix.

(*a*) The *uncinate fasciculus* passes across the bottom of the lateral cerebral fissure, and unites the gyri of the frontal lobe with the anterior end of the temporal lobe.

(*b*) The *cingulum* is contained within the cingulate gyrus. Beginning in front at the anterior perforated substance, it passes forwards and upwards parallel with the rostrum and genu, runs backwards above the body of the corpus callosum, turns round the splenium, and ends in the hippocampal gyrus.

(*c*) The *superior longitudinal fasciculus* passes backwards from the frontal lobe above the lentiform nucleus and insula; some of its fibres end in the

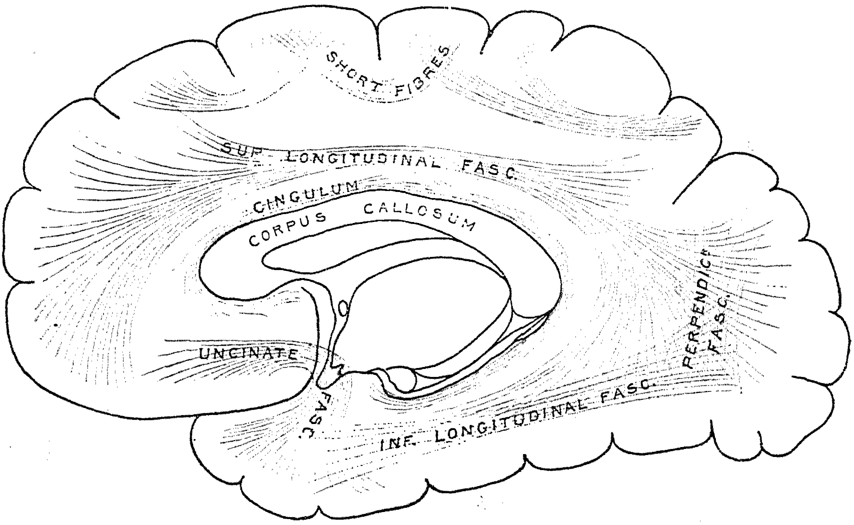
occipital lobe, and others curve downwards and forwards into the temporal lobe.

(*d*) The *inferior longitudinal fasciculus* connects the temporal and occipital lobes, running along the lateral walls of the inferior and posterior cornua of the lateral ventricle.

(*e*) The *perpendicular fasciculus* runs vertically through the front part of the occipital lobe, and connects the inferior parietal lobule with the fusiform gyrus.

(*f*) The *occipitofrontal fasciculus* passes backwards from the frontal lobe, along the lateral border of the caudate nucleus, and on the medial aspect of the corona radiata; its fibres radiate in a fan-like manner and pass into the occipital and temporal lobes, lateral to the posterior and inferior cornua. Dejerine regards the fibres of the tapetum as being derived from this fasciculus, and not from the corpus callosum.

Fig. 862.—A diagram showing the principal systems of association fibres in the cerebrum.



(*g*) The *fornix* connects the hippocampal gyrus with the corpus mamillare, and, by means of the mamillothalamic fasciculus, with the thalamus (p. 838). Through the fibres of the hippocampal commissure it probably also unites the right and left hippocampal gyri.

The **grey substance of the hemisphere** is divided into: (1) that of the cerebral cortex which covers the surfaces of the hemispheres, and (2) that of the caudate nucleus, the lentiform nucleus, the claustrum, and the nucleus amygdalæ.

The Structure of the Cerebral Cortex (fig. 863)

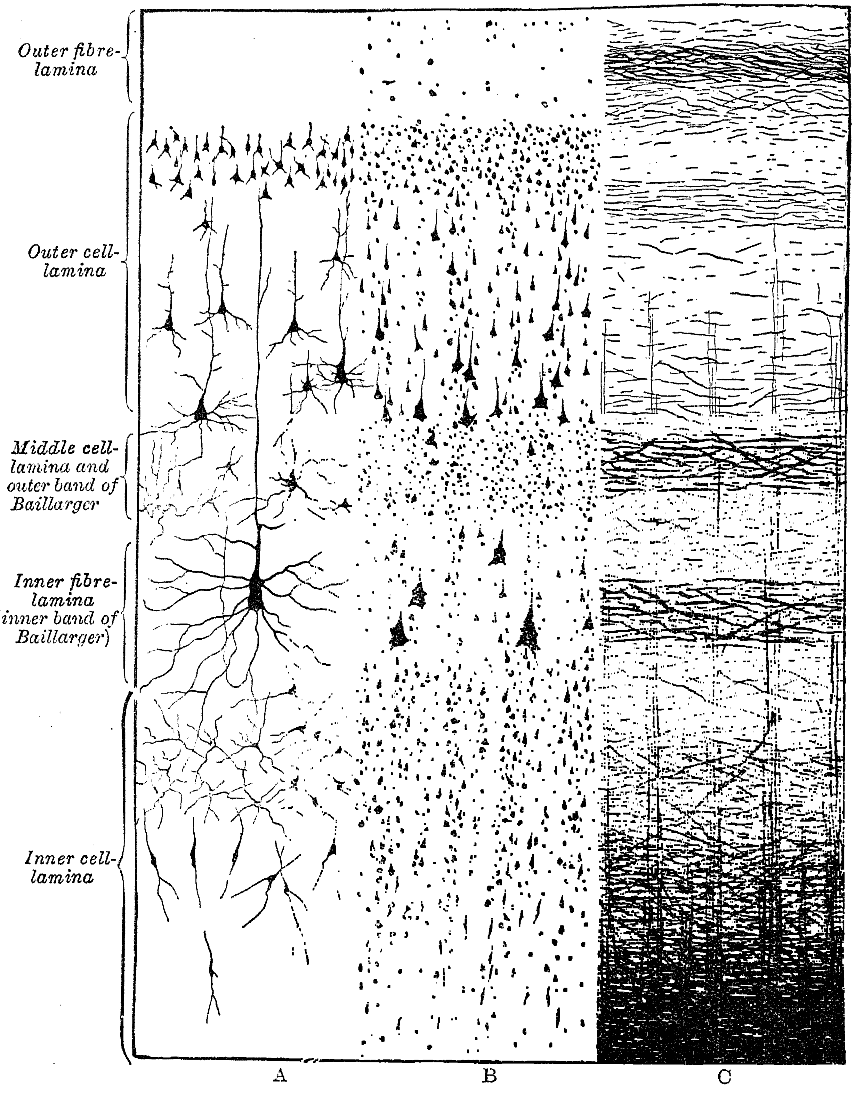
The cerebral cortex differs in thickness and structure in different parts of the hemisphere. It is thinner in the occipital region than in the anterior and posterior central gyri, and it is also much thinner in the depths of the sulci than on the summits of the gyri.

The cortex is made up of nerve-cells of varying size and shape, and of nerve-fibres which are either medullated or naked axis-cylinders, imbedded in a matrix of neuroglia. According to J. S. Bolton, it exhibits five layers:

1. The outer fibre-lamina (molecular or plexiform layer).
2. The outer cell-lamina.
3. The middle cell-lamina (layer of granules and outer band of Baillarger).
4. The inner fibre-lamina (inner band of Baillarger).
5. The inner cell-lamina (polymorphous layer).

1. The **outer fibre-lamina.**—The superficial part of this layer consists of a stratum of medullated nerve-fibres (plexus of Exner), running parallel with the surface. The deeper part is largely composed of the dendrites of cells from the subjacent laminæ. It contains also a few nerve-cells, and the

FIG. 863.—A diagram showing the layers of cells and fibres in the grey substance of the cortex of the human cerebral hemisphere, according to the histological methods of Golgi, Nissl and Weigert. After Brodmann; from Luciani's Physiology (Macmillan & Co., Ltd.).



A. Stained by the method of Golgi; B. by that of Nissl; C. by that of Weigert.

terminations of fibres which run into the cortex from the white substance of the hemisphere. The cells are of two kinds: (1) small irregular cells with a varying number of dendrites and short axons; (2) fusiform cells with their long axes parallel with the surface; the dendrites and the axons of the latter run horizontally, and the axons give off numerous collaterals. The distribution of the axons of both types of cell is limited to the outer fibre-lamina.

2. The **outer cell-lamina** contains many pyramidal nerve-cells; these are small (10μ to 15μ long) in the superficial, but large (20μ to 30μ) in the deep, part of the lamina. Each pyramidal cell contains granular pigment and a

large round or oval nucleus, and the apex of the cell is directed towards the surface. The axon arises from the base of the cell, and runs into the central white substance, giving off collaterals in its course, and being distributed as a projection, association, or commissural fibre. The apical and basal parts of the cell give off dendrites ; the apical dendrite ends in the outer fibre-lamina by dividing into numerous branches, all of which may be seen, when stained by the silver or methylene blue method, to be studded with bristle-like processes.

3. The **middle cell-lamina** or layer of granules consists chiefly of small stellate cells, but some pyramidal cells are also present in its deepest part. The axons of the stellate cells run a short course, and terminate either in the middle or outer cell-lamina. The axons of some of the pyramidal cells descend for a short distance and then turn back and end in the outer cell-lamina ; the axons of others run into the central white substance. In this lamina a well-marked stratum of nerve-fibres (*outer band of Baillarger*) runs parallel with the cortex.

In the visuosensory area of the occipital lobe (p. 871) the middle cell-lamina consists of two layers, separated by the outer band of Baillarger, which is here named the *band of Gennari.*

4. The **inner fibre-lamina** is composed of medullated nerve-fibres running parallel with the surface, and forming the *inner band of Baillarger.* In the anterior central gyrus and in the paracentral lobule it contains large pyramidal cells, the *giant-cells of Betz,* which are often solitary, but may occur in groups of three to five. These cells may be 50μ long and 40μ broad ; in the paracentral lobule they attain a length of 65μ.

5. The **inner cell-lamina** or polymorphous layer contains cells of various shapes—fusiform, oval, triangular, or stellate. Their dendrites are directed outwards, but do not reach the molecular layer ; most of their axons pass into the subjacent white substance. The axons of a few of these cells (cells of Golgi's second type) are short, and terminate in the adjacent grey substance. The *cells of Martinotti* in the inner cell-lamina are pyramidal in shape with their bases directed towards the surface ; their dendrites are short, and their axons pass out into the outer fibre-lamina, where they form an extensive horizontal arborisation.

In addition to the bands of medullated fibres described above as running parallel with the surface (*tangential fibres*), there are many deep tangential fibres in the lower part of the inner cell-lamina. The tangential fibres consist of (*a*) the collaterals of the axons of the pyramidal and polymorphous cells, and of the cells of Martinotti ; (*b*) the branching axons of Golgi's cells ; (*c*) the collaterals and terminal arborisations of the projection, commissural, and association fibres. *Radial fibres* also occur in the cortex and consist of, (*a*) the axons of the pyramidal and polymorphous cells descending into the white substance, and (*b*) the terminations of projection, commissural, or association fibres, ascending to end in the cortex. The axons of the cells of Martinotti are also ascending fibres.

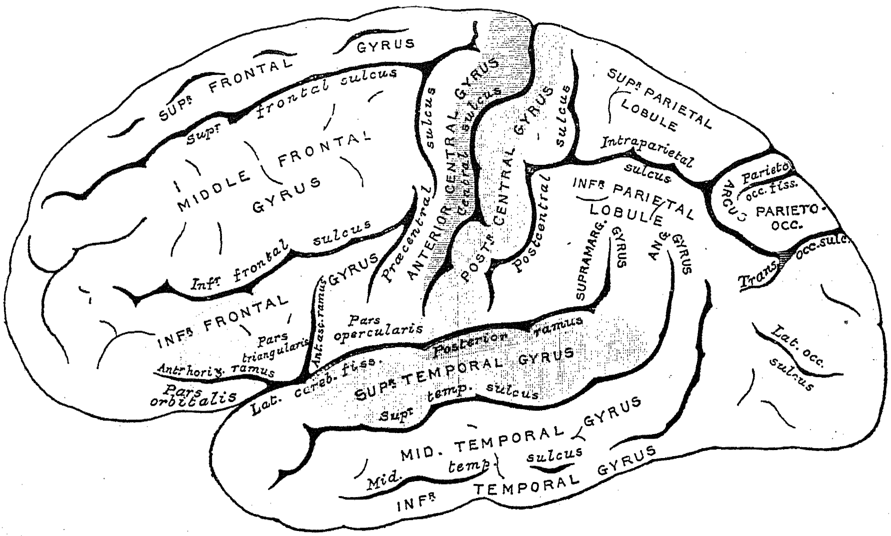
The **development of the laminæ of the cortex.** The inner cell-lamina is the first to appear in the course of development, and in the sixth month of fœtal life it has attained three-fourths of its adult depth. The inner fibre-lamina is associated with the inner cell-lamina, and although it does not appear until the sixth month of fœtal life, it reaches its full depth very quickly. The middle cell-lamina can be distinguished in the sixth month of fœtal life ; at this period it is one-half, and at birth three-fourths of the depth which it finally attains. The outer cell-lamina is the last to develop, both ontogenetically and phylogenetically, and its depth varies with the intellectual capacity of the individual. The outer fibre-lamina is well developed at birth, and its further growth is associated with that of the outer cell-lamina.

SPECIAL TYPES OF CEREBRAL CORTEX

The histological investigations of Bevan Lewis, Bolton, Campbell, and Brodmann, the embryological researches of Flechsig, and the experimental work of Sherrington and many others, have shown that the cortex of the

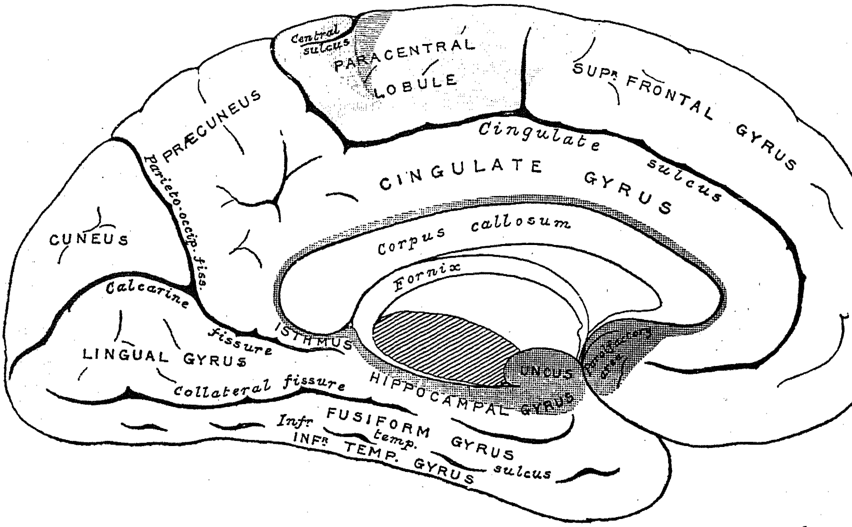
cerebral hemispheres can be mapped out into areas which possess different functions, and that the minute structure of the cortex varies characteristically in these different areas. The anterior central gyrus (motor area), the convolutions

FIG. 864.—The areas of localisation on the lateral surface of the left cerebral hemisphere.



Motor area in red. Area of general sensations in blue. Auditory area in green. Visual area in yellow. The psychic portions are in lighter tints.

FIG. 865.—The areas of localisation on the medial surface of the left cerebral hemisphere.



Motor area in red. Area of general sensations in blue. Visual area in yellow. Olfactory area in purple. The psychic portions are in lighter tints.

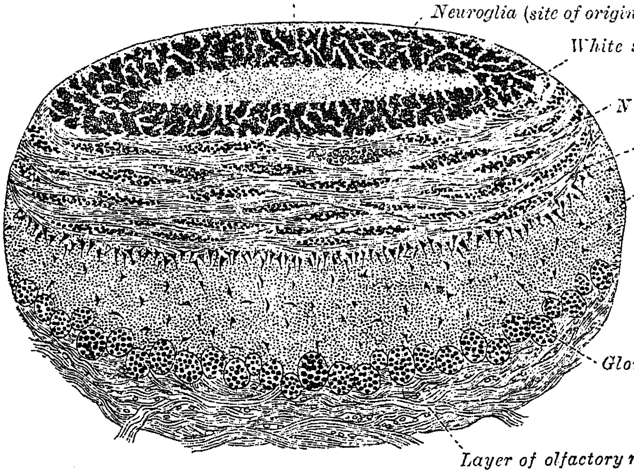
bounding the calcarine fissure (visuosensory area), the prefrontal district (associational area), and the hippocampal gyrus may be taken as types.

The **motor area** (figs. 864, 865) is characterised by the presence of the giant-cells of Betz in the inner fibre-lamina, and by the absence or very slight development of the middle cell-lamina or layer of granules. Physiological investigations show that the centres for the lower limb are located on the highest part of the anterior central gyrus and its continuation on to the paracentral lobule; those for the trunk are on the upper portion, and those for the upper

limb on the middle portion of the anterior central gyrus. The facial centres are situated on the lower part of the same gyrus, those for the tongue, larynx, muscles of mastication, and pharynx on the frontal operculum, while those for the eye movements occupy the posterior end of the middle frontal gyrus.

The **visuosensory area** (figs. 855, 864) is sometimes named the *area striata* because, in section, it presents a striated appearance produced by a greatly thickened outer band of Baillarger (band of Gennari); there is also a second layer of granules between this band and the outer cell-lamina. When blindness exists, the band of Gennari and the layers of granules superficial to it are diminished in depth, the former by as much as 50 per cent. in old-standing cases of optic atrophy. During development the visuosensory area matures rapidly; its outer cell-lamina develops early, but in the adult is only five-ninths of the depth of the same layer in the prefrontal region. The visuosensory area is surrounded by a zone 1 cm. or more in breadth, known as the **visuopsychic area.** In this zone the second layer of granules which is present in the visuosensory area suddenly ceases, and the outer cell-lamina is more developed.

FIG. 866.—A coronal section through the olfactory bulb. (Schwalbe.)



The **auditosensory area** occupies the anterior transverse temporal gyrus (p. 848) and the upper part of the middle one-third of the superior temporal gyrus; the **auditopsychic area** surrounds the auditosensory area but has not been exactly defined. The area for the *sense of taste* is probably in the uncus and hippocampal gyrus, and that for the *sense of smell* in the rhinencephalon. The area for *heat, cold,* and *pain* is somewhat diffuse, but the areas for the *tactile* and *muscular senses* are located mainly in the posterior central gyrus (fig. 864). Destruction of the cerebral cortex does not produce total loss of cutaneous sensibility; this is strikingly true of painful sensations which possibly have centres in the thalamus.

The **associational areas** are three in number: (1) the prefrontal, (2) an area occupying the posterior portions of the temporal and parietal lobes, and (3) the insula. The prefrontal associational area is especially characteristic of the human brain, and it may be taken as the type. It is distinguished by the great development of the outer cell-lamina; the cells of this lamina are undifferentiated in the sixth month of fœtal life, and the lamina is only one-fourth of its adult depth; it is the only layer which varies appreciably in depth in normal brains, and it is under-developed in idiots and imbeciles; it is the last to be evolved and the first to retrogress (Bolton).

The minute structure of the hippocampus, the fascia dentata, and the olfactory bulb calls for special description.

In the **hippocampus** the white substance is represented by a layer termed the *alveus* which lies next the ventricular ependyma; through the alveus fibres

pass from the hippocampus into the fimbria hippocampi and crura of the fornix. The grey substance consists of: (1) a layer of large pyramidal cells next the alveus; (2) a layer occupied by the apical dendrons of these pyramidal cells, and called the *stratum radiatum*; (3) a molecular layer, the deeper part of which, called the *stratum laciniosum*, exhibits interlacing fibres and dendrites, and contains numerous small, angular nerve-cells; near the dentate gyrus there is a layer of small cells, internal to the stratum laciniosum, known as the *stratum granulosum*.

In the **fascia dentata hippocampi** (dentate gyrus) the molecular layer contains some pyramidal cells, while the layer of pyramidal cells is almost entirely represented by small ovoid cells.

The **olfactory bulb**.—In many animals the olfactory bulb contains a cavity which communicates through the olfactory tract with the lateral ventricle. In man the original cavity is filled by neuroglia and its wall becomes thickened, but much more so on its ventral than on its dorsal aspect. Its dorsal part contains a small amount of grey and white substance, but this is scanty and ill-defined. A section through the ventral part (fig. 866) shows it to consist of the following layers from without inwards: (1) A layer of olfactory nerve-fibres.—These fibres are the non-medullated axons prolonged from the olfactory cells of the nasal cavity, and reach the bulb by passing through the lamina cribrosa of the ethmoidal bone. At first they cover the bulb, and then penetrate it to end by forming synapses with the dendrites of the mitral cells, presently to be described. (2) Glomerular layer.—This contains numerous spheroidal bodies, termed *glomeruli*, each of which is produced by the branching and interlacement of the terminations of one or more olfactory nerve-fibres with the descending dendrite of a mitral cell (fig. 876). (3) Molecular layer.—This is formed of a matrix of neuroglia, imbedded in which are the *mitral cells*. These cells are pyramidal in shape, and the basal part of each gives off a thick dendrite which descends into one of the glomeruli, where it ends as indicated above, and others which interlace with similar dendrites of neighbouring mitral cells. The axons of the mitral cells pass into the next layer, and, bending backwards, are continued into the olfactory tract. (4) Nerve-fibre layer.—This lies next the central core of neuroglia; its fibres consist of the axons of the mitral cells, and pass to the brain; some efferent fibres are, however, also present, and end in the molecular layer, but nothing is known as to their exact origin.

The **weight of the brain**.—The average weight of the brain, in the adult male, is about 1380 gms.; that of the female, about 1250 gms. In the male, the maximum weight out of 278 cases was 1840 gms. and the minimum weight 964 gms. The maximum weight of the adult female brain, out of 191 cases, was 1585 gms. and the minimum weight 879 gms. The brain increases rapidly during the first four years of life, and reaches its maximum weight by about the twentieth year. As age advances, the brain decreases slowly in weight; in old age the decrease takes place more rapidly, and may amount to about 28 gms.

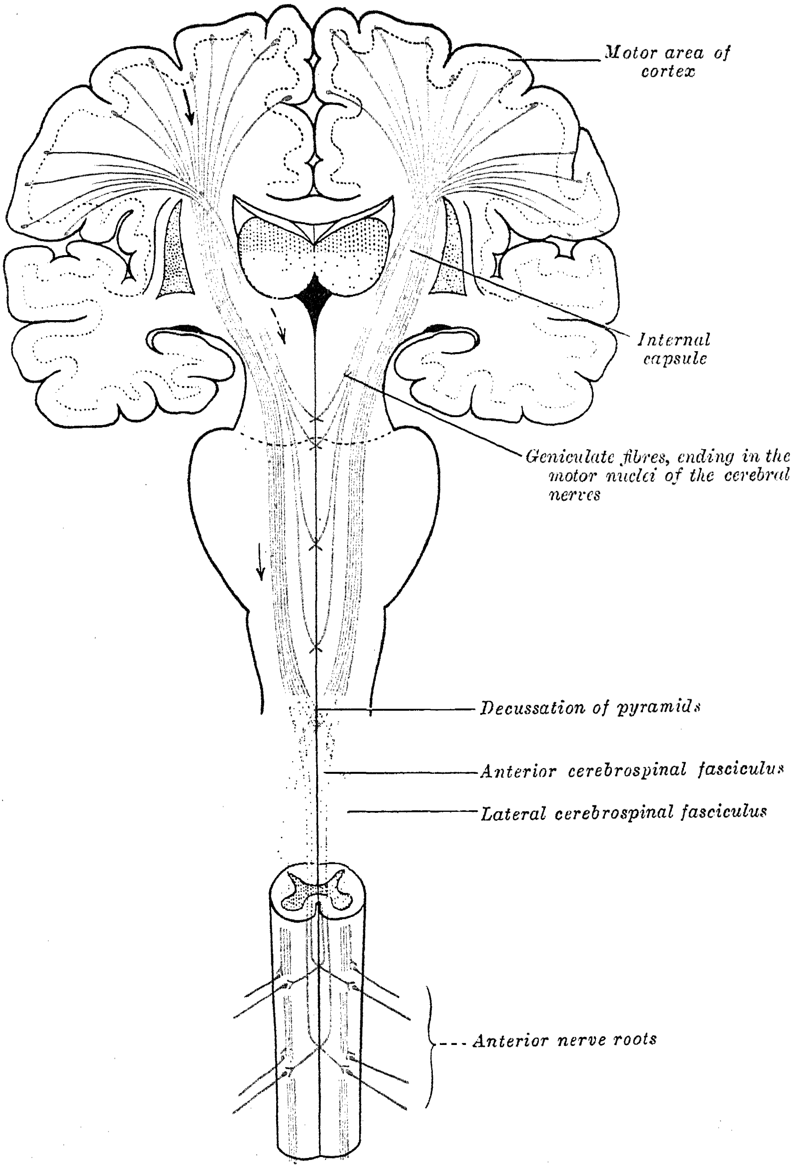
Applied Anatomy.—The *internal capsule* is often the seat of hæmorrhage from the lenticulostriate and lenticulo-optic arteries (Charcot's 'arteries of cerebral hæmorrhage'), or of thrombosis, in patients whose vessels are weakened by old age or disease. A 'stroke,' or 'apoplexy,' is the result; blood is effused from the ruptured vessel and tears up the surrounding brain tissue, and also interferes with the neighbouring fibres by the compression set up by its mass. If the hæmorrhage is sudden and at all large, rapid and complete loss of consciousness follows, with paralysis of the opposite side of the body and loss of control over the sphincters. If it is the occipital part of the internal capsule that is involved, the paralysis will be more marked in the leg than in the arm, and will be associated with hemianæsthesia, and also with homonymous hemianopsia or blindness of the corresponding halves of the two retinæ, the patient being unable to see objects on the opposite side of the body. If the hæmorrhage is very extensive blood often makes its way into the ventricles, and death may follow in a few hours or days without recovery of consciousness, and with hyperpyrexia. If the hæmorrhage is small, consciousness is soon regained, and a fair degree of recovery from the paralysis follows, particularly in the leg. If the hæmorrhage takes place very slowly, the hemiplegia sets in gradually (ingravescent apoplexy), with headache and gradual clouding of the faculties. It is the upper motor neuron (p. 874) that is injured in cerebral hæmorrhage; hence the muscles on the affected side of the body become spastic, with increased reflexes, while such muscular atrophy as follows is mainly due to disuse. The cerebral arteries are liable to sudden obstruction by embolism in persons with heart disease, and by thrombosis in those with diseased arteries. The effects of either embolism or thrombosis here are comparable with those of cerebral hæmorrhage,

though the resulting hemiplegia or paralysis is often more gradual in its onset, and less severe in its general results.

The Chief Nerve Tracts.

The anatomy of the various parts of the central nervous system having been described, a short account will now be given of the chief ascending and descending nerve-tracts connecting the brain and the medulla spinalis. This may be effected most conveniently by grouping them as follows: (*a*) the motor (descending) tracts, (*b*) the sensory (ascending) tracts, and (*c*) the cerebellar systems (ascending and descending).

Fig. 867.—The principal motor tracts. (Modified from Poirier.)



The Motor Tracts.

Included under this heading are, (*a*) the principal motor tracts, originating in the cerebral cortex, and (*b*) the secondary motor tracts originating in the basal ganglia.

The principal motor tracts (fig. 867).—The constituent fibres of these tracts are the axis-cylinder processes of the cells of Betz situated in the motor area of the cortex. The

fibres converge as they descend through the corona radiata, and pass between the lentiform nucleus and thalamus, in the genu and in the anterior two-thirds of the occipital part of the internal capsule; those in the genu are named the geniculate fibres, the others the cerebrospinal fibres. Both sets of fibres proceed downwards, through the middle three-fifths of the base of the cerebral peduncle, and then the geniculate fibres cross the middle line, and end by arborising around the cells of the motor nuclei of the cerebral nerves. The cerebrospinal fibres are continued downwards into the pyramids of the medulla oblongata, and thence proceed by one of two paths. The fibres nearest to the anterior median fissure cross the middle line, forming the *decussation of the pyramids*, and descend in the opposite lateral funiculus of the medulla spinalis, as the lateral cerebrospinal fasciculus (crossed pyramidal tract). Throughout the length of the medulla spinalis, fibres from this fasciculus pass into the grey substance, to end by arborising around cells of the posterior column, the axons of which in turn make contact with the motor cells of the anterior column. The more laterally placed cerebrospinal fibres do not decussate in the medulla oblongata, but descend as the anterior cerebrospinal fasciculus (direct pyramidal tract); in each segment of the upper part of the medulla spinalis some of these fibres cross in the anterior white commissure, with the result that all end in the grey substance of the opposite side. There is considerable variation in the extent to which decussation takes place in the medulla oblongata; about two-thirds or three-fourths of the cerebrospinal fibres usually decussate in the medulla oblongata and the remainder in the medulla spinalis.

The secondary motor tracts.—While the presence of a motor path distinct from the principal motor tracts has for some time been surmised on clinical grounds, it is only recently that anatomical details of it have become available, and many of these are still under investigation. In this summary it will be sufficient to indicate that the chief nuclei involved are the globus pallidus of the corpus striatum and the red nucleus of the mid-brain. The main pathway is from the globus pallidus to the red nucleus, and thence to the opposite side of the medulla spinalis by the rubrospinal tract. Secondary pathways probably begin in the globus pallidus and run to the substantia nigra and formatio reticularis, and proceed by successive neurons downwards to the medulla spinalis. All these descending fibres ultimately reach and arborise round the motor cells of the cerebral nerve nuclei or of the anterior grey column of the medulla spinalis.

The axons of the motor cells in the cerebral nuclei proceed through the cerebral nerves, while those of the cells in the anterior grey column of the medulla spinalis pass out in the anterior roots of the spinal nerves, forming thus in each instance a *final common motor pathway*, along which impulses are conducted to the muscles of the head, trunk and limbs. For clinical purposes the neurons constituting the final motor pathway are grouped as the *lower motor neurons*, while the other neurons of the motor pathway form the group of *upper motor neurons*.

The Sensory Tracts.

The **sensory impulses** traversing the cerebrospinal axis may be resolved into three groups: (1) *exteroceptive*, initiated on the surface of the body, and comprising the sensations of touch, temperature, pain, and the special senses; (2) *interoceptive*, conveying impulses from the visceral systems; and (3) *proprioceptive*, which begin in the muscles, tendons and joints, and are associated with the muscle sense.

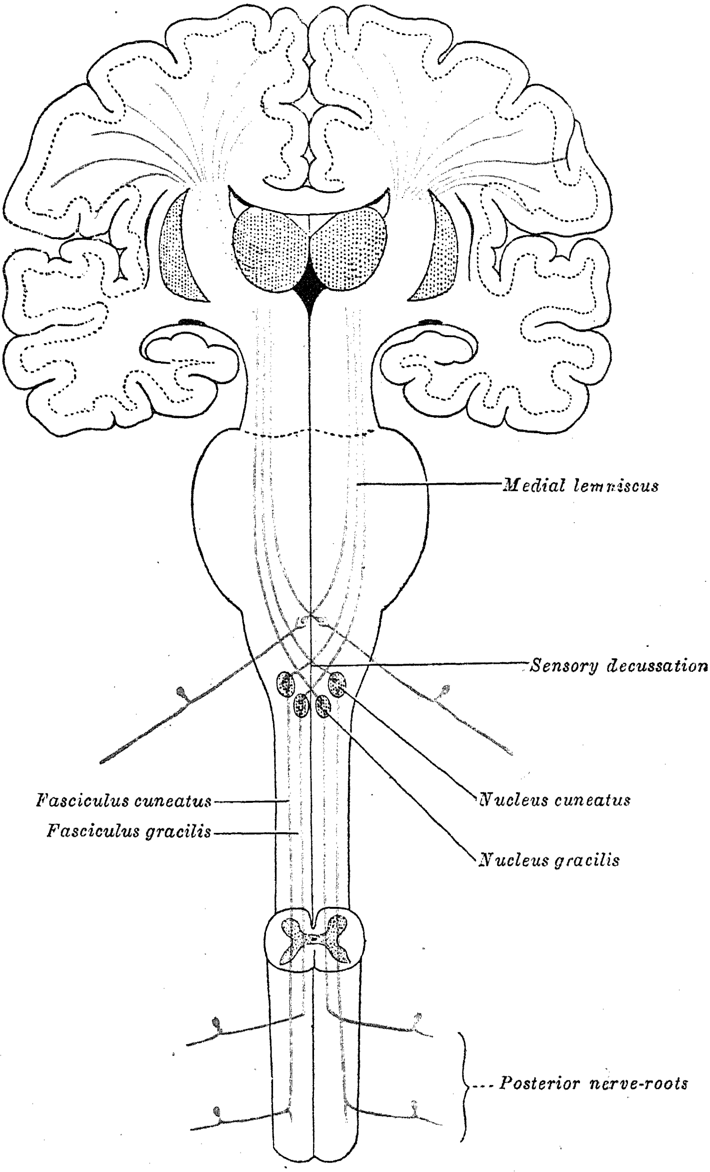
Information as to the interoceptive group is still so vague that it cannot be described satisfactorily in this summary. The proprioceptive group includes some fibres which convey sensations of position and movement, not usually very clearly defined in consciousness, but represented by a pathway that may be conveniently described with the other sensory tracts belonging to the exteroceptive group. The pathways of the special senses have been already described in sufficient detail, so that in this section are included the fibre-tracts for (*a*) the muscle sense, (*b*) the tactile sense, (*c*) the pain and (*d*) temperature senses. The first neurons of all these are the cells of the posterior root ganglia of the spinal nerves, and of the ganglia on the cerebral sensory nerves; the fibres conveying the different impulses therefore all enter the cerebrospinal axis together, but immediately after entering separate into their respective tracts.

Muscle sense.—Sensory impulses are conveyed to the medulla spinalis through the posterior roots of the spinal nerves. On entering the medulla spinalis these root-fibres divide into descending and ascending branches; the descending branches soon enter and ramify in the grey substance; the majority of the ascending branches are continued into the posterior funiculi where they join the fasciculus gracilis and fasciculus cuneatus. These fasciculi end by arborising around the cells of the nucleus gracilis and nucleus cuneatus in the medulla oblongata (fig. 868), and from these cells the fibres of the medial lemniscus take origin and cross to the opposite side in the sensory decussation. In its further course the medial lemniscus receives fibres from the terminal nuclei of the ordinary sensory cerebral nerves of the opposite side. Ascending through the cerebral peduncle the medial lemniscus gives off a few fibres to the lentiform nucleus and insula, but the greater part of it is carried into the thalamus where its fibres end. From the cells of the thalamus the fibres of the third link in the chain arise and pass to the cerebral cortex behind the central sulcus.

Tactile sense.—Sensory impulses enter the medulla spinalis by fibres of the posterior roots of the spinal nerves. Some of the entering fibres arborise at once with cells in the

posterior column of grey matter; others ascend for varying distances, and end around the posterior column cells of higher segments; from these cells fibres arise and cross to the opposite side to run up in the anterior spinothalamic tract. A third set of longer fibres ascends as far as the nucleus gracilis and nucleus cuneatus, and ends by arborising around the cells of these nuclei; the fibres from those cells cross in the sensory decussation in

FIG. 868.—The pathway of the muscle sense. (Modified from Poirier.)

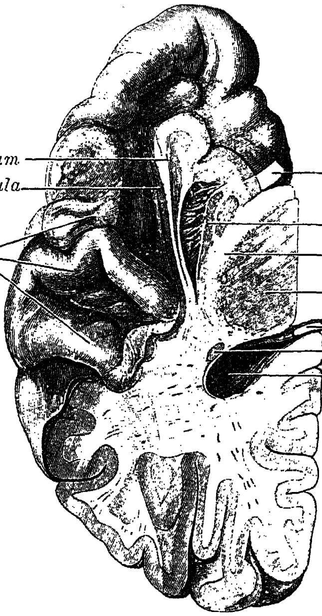


the medulla oblongata, and join the anterior spinothalamic tract, which is continued up through the pons and mid-brain to the thalamus where it ends; the impulse is finally carried by the neurons of the thalamus to the cerebral cortex behind the central sulcus.

Pain and temperature senses.—The fibres conveying these sensory impulses travel together. They enter the medulla spinalis through the posterior nerve-roots, and at once arborise around the cells of the posterior grey column. The fibres from these cells cross to the opposite side of the medulla spinalis where most of them form a long pathway, the lateral spinothalamic tract, which runs through the medulla oblongata dorsal to the inferior olive and then joins the medial lemniscus and is continued to the thalamus. Some

it is limited by the inferolateral border of the hemisphere. It is divided into superior, middle, and inferior gyri by the superior and middle temporal sulci. The *superior temporal sulcus* traverses the temporal lobe, some little distance below, but parallel with, the posterior ramus of the lateral fissure ; and therefore it is often termed the *parallel sulcus*. The *middle temporal sulcus* takes the same direction as the superior, but is situated at a lower level, and is usually subdivided into two or more parts. The *superior temporal gyrus* lies between the posterior ramus of the lateral cerebral fissure and the superior temporal sulcus, and is continuous behind with the supramarginal and angular gyri of the parietal lobe. The *middle temporal gyrus* is between the superior and middle temporal sulci, and is joined posteriorly with the angular gyrus. The

FIG. 844.—A section showing the upper surface of the left temporal lobe.



inferior temporal gyrus is placed below the middle temporal sulcus, and is connected behind with the inferior occipital gyrus ; it also extends round the inferolateral border on to the inferior surface of the temporal lobe, where it is limited by the inferior temporal sulcus.

The *inferior surface* is concave, and is continuous posteriorly with the tentorial surface of the occipital lobe. It is traversed by the *inferior temporal sulcus*, which extends from near the occipital pole behind, to within a short distance of the temporal pole in front, but is frequently subdivided by bridging gyri. Lateral to this fissure is the narrow tentorial part of the inferior temporal gyrus, and medial to it the *fusiform gyrus*, which extends from the occipital to the temporal pole ; this gyrus is limited medially by the collateral fissure, which separates it from the lingual gyrus behind and from the hippocampal gyrus in front.

The **insula** (island of Reil) (fig. 845) lies deeply in the lateral cerebral fissure, and is surrounded by the circular sulcus (p. 846) ; it can only be seen when the lips of the lateral cerebral fissure are widely separated, since it is overlapped and hidden by the gyri which bound the fissure. These gyri are termed the *opercula of the insula* ; they are separated from each other by the three rami of the lateral fissure, and are named the orbital, frontal, fronto-parietal, and temporal opercula. The *orbital operculum* lies below the anterior horizontal ramus of the fissure, the *frontal* between this and the anterior ascending ramus, the *frontoparietal* between the anterior ascending ramus and

foot brings on plantar flexion of the toes), if present, show that the reflex arcs on whose integrity their existence depends are intact; but they often are absent in health and so cannot be trusted to indicate disease. The *deep reflexes or tendon reactions*, such as the knee-jerk, or the tendo calcaneus jerk, are increased in chronic degeneration of, or gradually increasing pressure on, the cerebrospinal fibres (upper motor neuron), in nervous or hysterical patients, and when the irritability of the cells of the anterior column (lower motor neuron) is increased, as happens in tetanus or in poisoning by strychnine. They are lost when the lower motor or lower sensory neurons are diseased, and in a few other conditions; absence of the knee-jerk is very rare in health, and suggests disease in some part of its reflex arc, in the third and fourth lumbar segments of the cord, or else, more rarely, grave intracranial or spinal disease cutting off the lower from the higher nervous centres. The *organic reflexes* of the pupil, bladder, and rectum are of the greatest practical importance. The commonest defect in the reflexes of the pupil is reflex iridoplegia, or failure to contract on exposure to light, without failure to contract on convergence or accommodation (' Argyll Robertson ' pupil). The pupil is also contracted (miosis), and may or may not dilate when the skin of the neck is pinched (the ciliospinal reflex). Micturition is a spinal reflex much under the control of the brain; if the centre for micturition in the second sacral segment is destroyed the sphincter and the walls of the bladder are paralysed, the bladder becomes distended with urine, and incontinence from overflow results. If this centre escapes injury but is cut off more or less completely from impulses descending to it from above, there will be more or less interference with micturition. This varies in degree from the ' precipitate micturition ' of tabetic patients, who must perforce hurry to pass water the moment the impulse seizes them, to the state of ' reflex incontinence,' when the bladder automatically empties itself from time to time, almost without the patient's knowledge. Defæcation is a very similar spinal reflex, and is liable to very similar disorders of function.

The *upper motor neuron* (p. 874) is affected in hemiplegia, the *lower motor neuron* (p. 874) in infantile spinal paralysis; both these systems of neurons are diseased together in the somewhat rare disorders known as amyotrophic lateral sclerosis and progressive muscular atrophy. The chief symptom here is wasting and weakness in certain groups of muscles; the palsy will be flaccid, with loss of the reflexes, or spastic, with increased reflexes, according as the degeneration mainly involves the lower or the upper motor neuron. The sphincters are affected only in the later stages of these diseases.

Pathological changes in the *lowest sensory neuron* are the cause of tabes dorsalis or locomotor ataxy, which occurs almost entirely in adults who have had syphilis. In the early or pre-ataxic stage the patient may exhibit the Argyll Robertson pupil (see above), and loss of knee-jerks, and complain of sharp, stabbing pains (' lightning pains ') in the limbs, difficult or precipitate micturition, and sometimes of severe and painful attacks of indigestion (gastric crises). In the second or ataxic stage, coming on perhaps years later, he will complain, in addition, of interference with his powers of getting about and turning, although his muscular strength is well preserved. He is unable to stand steady with his eyes shut or in the dark, his gait becomes exaggerated and stamping in character, he has to use a stout stick to walk with, and he may suffer from painful crises in various parts of the body. Control over the sphincters is further weakened, and on examination there will be found marked incoordination of the limbs, zones of anæsthesia about the trunk or down the limbs, and marked analgesia (or insensitiveness to pain) when pressure is applied to the bones, tendons, trachea, tongue, eyeballs, mammæ, and testes.* The ataxy progresses till the third or bedridden stage is reached; control over the sphincters is still further lost, and the patient is likely to die of intercurrent disease or of general paralysis of the insane.

No nervous disease is recognised as dependent upon degeneration of either the *intermediate* or *highest sensory neuron*.

THE MENINGES OF THE BRAIN AND MEDULLA SPINALIS

The brain and the medulla spinalis are enveloped by three membranes or meniages, named from without inwards: the dura mater, the arachnoid, and the pia mater.

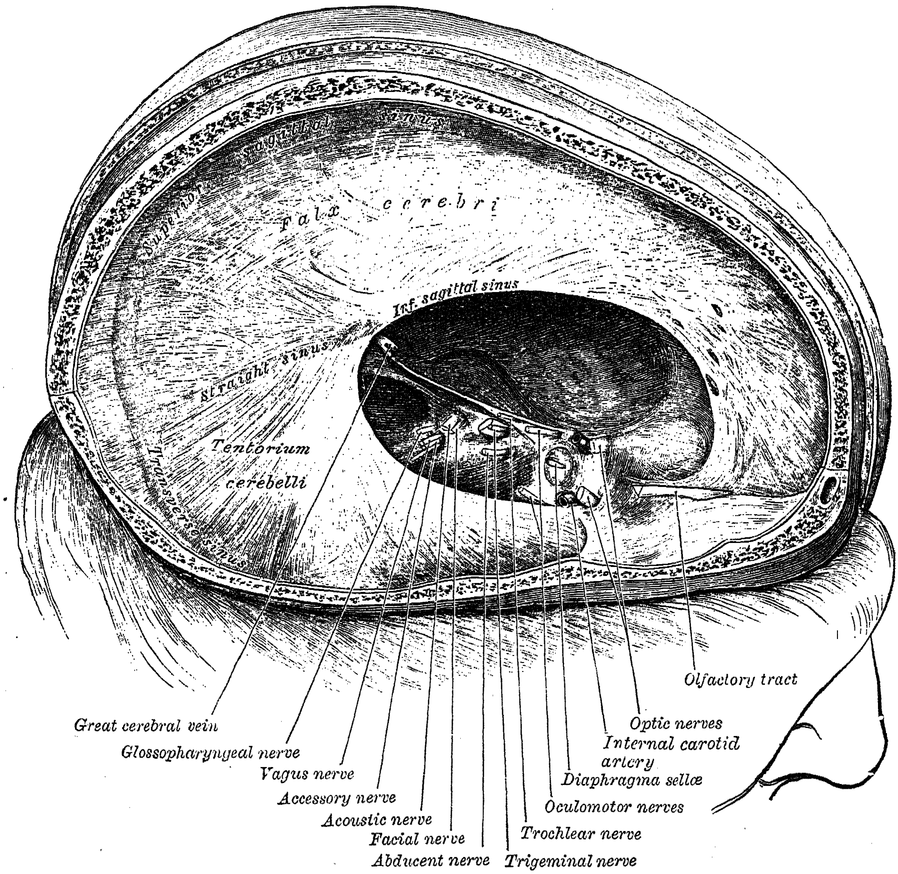
The Dura Mater

The **dura mater** is a thick and dense inelastic membrane. The portion of it which encloses the brain (cerebral dura mater) differs in several particulars from that which surrounds the medulla spinalis (spinal dura mater), and therefore it is necessary to describe them separately; the two parts, however, form one complete membrane, and are continuous with one another at the foramen magnum.

* J. Grasset, *Le Tabes, Maladie de la Sensibilité profonde*; Montpelier, 1909.

The **cerebral dura mater** lines the interior of the skull, and serves the two-fold purpose of an internal periosteum to the bones, and a protective membrane for the brain. It is composed of two layers, an inner or meningeal and an outer or endosteal; these are closely united, except along certain lines where they are separated by the venous sinuses which drain the blood from the brain (p. 717). The dura mater adheres to the inner surfaces of the cranial bones, and sends blood-vessels and fibrous processes into them, the adhesion being most marked at the sutures, at the base of the skull, and around the

FIG. 869.—The dura mater and its processes. Exposed by removing a part of the right half of the skull, and the brain.

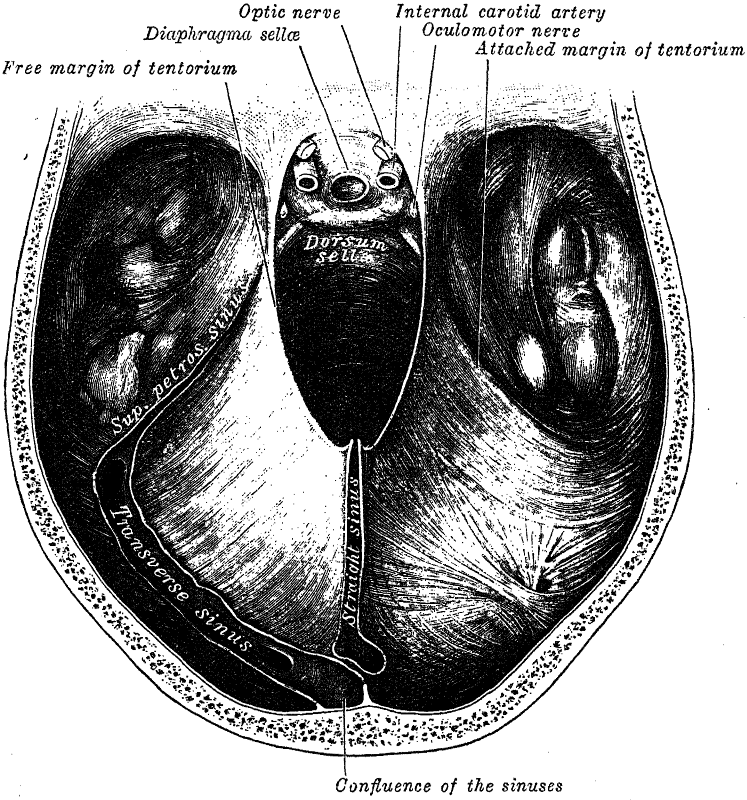


foramen magnum. The blood-vessels and fibrous processes are torn across when the dura mater is detached from the bones, and consequently the outer surface of the membrane presents a rough and fibrillated appearance; the inner surface is smooth and lined by a layer of endothelium. The dura mater is continuous through the sutures with the pericranium, and through the superior orbital fissure with the periosteal lining of the orbital cavity. It sends tubular sheaths on the cerebral nerves as the latter pass through the foramina at the base of the skull; outside the skull these sheaths fuse with the epineurium of the nerves; the sheath of the optic nerve blends anteriorly with the sclera of the bulb of the eye.

The cerebral dura mater sends inwards four processes or septa which divide the cranial cavity into a series of freely communicating spaces for the lodgment of the brain. These processes are named the falx cerebri, the tentorium cerebelli, the falx cerebelli, and the diaphragma sellæ.

The *falx cerebri* (fig. 869), so named from its sickle-like form, is a strong, arched process of dura mater which descends vertically in the longitudinal fissure between the cerebral hemispheres. It is narrow in front, where it is fixed to the crista galli of the ethmoidal bone; and broad behind, where it is attached to the middle line of the upper surface of the tentorium cerebelli; the narrow, anterior part is thin, and is frequently perforated by numerous apertures. The upper margin of the falx cerebri is convex, and attached to the inner surface of the skull on either side of the middle line, as far back as the internal occipital protuberance; the superior sagittal sinus runs along this

FIG. 870.—The tentorium cerebelli. Superior aspect.



margin. Its lower margin is free and concave, and contains the inferior sagittal sinus. The straight sinus runs along its attachment to the tentorium cerebelli.

The *tentorium cerebelli* (fig. 870) is an arched lamina of dura mater which covers the superior surface of the cerebellum, and supports the occipital lobes of the brain. Its concave, anterior border is free, and bounds a large oval opening, the *incisura tentorii*, which is occupied by the mesencephalon. Its convex, posterior border is attached behind to the lips of the transverse sulci on the inner surface of the occipital bone, and there encloses the transverse sinuses; in front, the posterior border is attached to the superior angles of the petrous parts of the temporal bones, enclosing the superior petrosal sinuses. At the apex of the petrous part of the temporal bone the free and attached borders cross one another; the free borders are fixed to the anterior, and the attached borders to the posterior, clinoid processes of the sphenoidal bone. As already stated, the posterior border of the falx cerebri is attached to the median line of the upper surface of the tentorium cerebelli, and the straight sinus lies in this line of attachment.

The *falx cerebelli* is a small, median sagittal, triangular process of dura mater which is situated below the tentorium cerebelli, and projects forwards into the posterior cerebellar notch. Its base, directed upwards, is attached to the posterior part of the median line of the tentorium cerebelli; its posterior margin contains the occipital sinus, and is fixed to the internal occipital crest; its apex frequently divides into two small folds, which are lost on the sides of the foramen magnum.

The *diaphragma sellæ* is a small circular horizontal fold of dura mater, which roofs the sella turcica and almost completely covers the hypophysis; a small opening in its centre transmits the infundibulum.

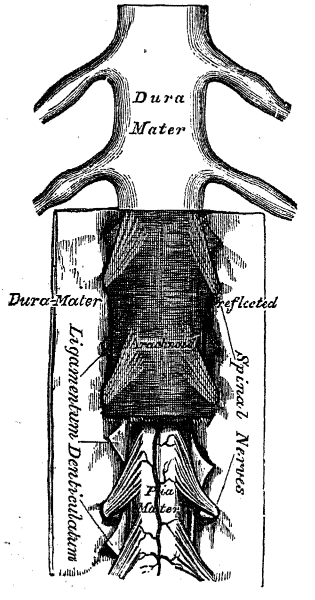
Structure.—The cranial dura mater consists of white fibrous tissue and elastic fibres arranged in flattened laminæ which are imperfectly separated by lacunar spaces and blood-vessels into the endosteal and meningeal layers, already referred to. The endosteal layer is the internal periosteum for the cranial bones, and contains the blood-vessels for their supply. At the margin of the foramen magnum it is continuous with the periosteum lining the vertebral canal. The meningeal layer is lined on its inner surface by a layer of nucleated endothelium.

The *arteries* of the dura mater are very numerous. Those in the anterior fossa of the skull are the anterior meningeal branches of the anterior and posterior ethmoidal and internal carotid arteries, and a branch from the middle meningeal artery. Those in the middle fossa are the middle and accessory meningeal branches of the internal maxillary artery; a branch from the ascending pharyngeal artery, which enters the skull through the foramen lacerum; branches from the internal carotid artery, and a recurrent branch from the lacrimal artery. Those in the posterior fossa are meningeal branches from the occipital artery, one entering the skull through the jugular foramen, and another through the mastoid foramen; the posterior meningeal branches of the vertebral artery; occasional meningeal branches from the ascending pharyngeal artery, entering the skull through the jugular foramen and hypoglossal canal; and a branch from the middle meningeal artery.

The *veins* returning the blood from the cranial dura mater anastomose with the diploic veins and end in the cranial blood-sinuses. Many of the meningeal veins do not open directly into the sinuses, but indirectly through a series of *venus lacunæ.* These lacunæ are found on either side of the superior sagittal sinus, especially near its middle portion, and are often invaginated by arachnoideal granulations; they communicate with the diploic and emissary veins.

The *nerves* of the cerebral dura mater are filaments from the semilunar ganglion of the trigeminal nerve, from the ophthalmic, maxillary, mandibular, vagus, and hypoglossal nerves, and from the sympathetic.

FIG. 871.—A portion of the medulla spinalis, showing its membranes.



The **spinal dura mater** (figs. 871, 874) forms a loose sheath around the medulla spinalis, and represents only the inner or meningeal layer of the cerebral dura mater; the outer or endosteal layer ceases at the foramen magnum, its place being taken by the periosteum lining the vertebral canal. The spinal dura mater is separated from the wall of the vertebral canal by a space, the *epidural space*, which contains a quantity of loose areolar tissue and a plexus of veins; the situation of these veins between the spinal dura mater and the periosteum of the vertebræ corresponds to that of the cranial sinuses between the meningeal and endosteal layers of the cerebral dura mater. The spinal dura mater is attached to the circumference of the foramen magnum, and to the second and third cervical vertebræ; it is also connected by fibrous slips to the posterior longitudinal ligament of the vertebræ, especially near the lower end of the vertebral canal. The subdural cavity ends at the lower border of the second sacral vertebræ; below this level the dura mater closely invests the filum terminale of the medulla spinalis and descends to the back of the coccyx, where it blends with the periosteum. The dura mater sends tubular prolongations on the roots of the spinal nerves and on the complete spinal nerves

as they pass through the intervertebral foramina. These prolongations are short in the upper part of the vertebral column, but gradually become longer below.

Structure.—The spinal dura mater resembles in structure the meningeal layer of the cranial dura mater; it consists of white fibrous and elastic tissue arranged in bands or lamellæ which, for the most part, are parallel with one another and have a longitudinal arrangement. Its internal surface is smooth and covered by a layer of endothelium. It is sparingly supplied with blood-vessels and nerves.

The Arachnoid

The **arachnoid** is a delicate membrane enveloping the brain and medulla spinalis and lying between the pia mater internally and the dura mater externally. It is separated from the dura mater by the *subdural space*, but here and there this space is traversed by isolated connective tissue trabeculæ, which are most numerous on the posterior surface of the medulla spinalis. It is separated from the pia mater by the *subarachnoid cavity* which is filled with cerebrospinal fluid.

The arachnoid surrounds the cerebral and spinal nerves, and encloses them in loose sheaths as far as their points of exit from the skull and vertebral canal.

The *cerebral part of the arachnoid* invests the brain loosely, and does not dip into the sulci between the gyri, nor into the fissures, with the exception of the longitudinal. On the upper surface of the brain it is thin and transparent; at the base it is thicker, and slightly opaque towards the central part, where it extends between the two temporal lobes in front of the pons, so as to leave a considerable interval between it and the pia mater.

The *spinal part of the arachnoid* (figs. 871, 874) is a thin, delicate, tubular membrane loosely investing the medulla spinalis. Above, it is continuous with the cerebral arachnoid; below, it widens out, invests the cauda equina, and ends at the level of the lower border of the second sacral vertebra

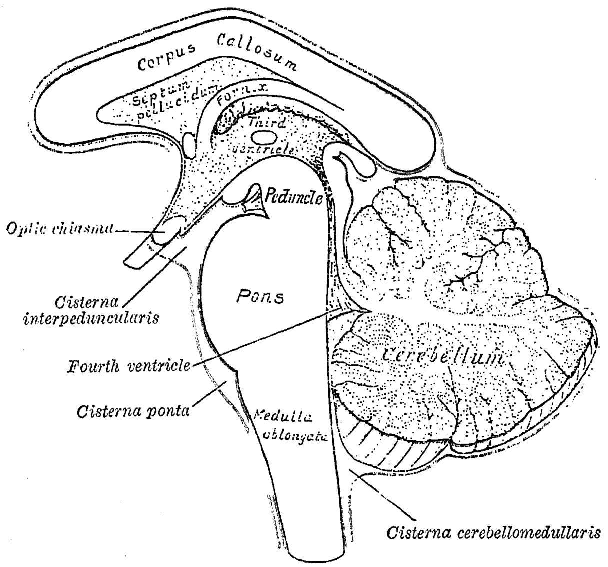
Structure.—The arachnoid consists of bundles of white fibrous and elastic tissue intimately blended together. Its outer surface is covered with a layer of endothelium. Vessels of considerable size, but few in number, and, according to Bochdalek, a rich plexus of nerves derived from the motor root of the trigeminal, the facial, and the accessory nerves, are found in the cerebral part of the arachnoid.

The **subarachnoid cavity** is the interval between the arachnoid and pia mater. It contains the cerebrospinal fluid and the larger blood-vessels of the brain, and is traversed by a network of delicate connective tissue trabeculæ, which connect the arachnoid to the pia mater. The pia mater and the arachnoid are in close contact on the summits of the cerebral gyri; but where the arachnoid bridges the sulci, angular spaces are left, in which the subarachnoid trabecular tissue is found. At certain parts of the base of the brain, the arachnoid is separated from the pia mater by wide intervals, which communicate freely with each other and are named *subarachnoid cisternæ*; in these the subarachnoid tissue is less abundant.

The **subarachnoid cisternæ** (fig. 872).—The *cisterna cerebellomedullaris* (cisterna magna) is triangular on sagittal section, and is formed by the arachnoid bridging the interval between the medulla oblongata and the under surface of the cerebellum; it is continuous below with the subarachnoid cavity of the medulla spinalis. The *cisterna pontis* is a considerable space on the ventral aspect of the pons. It contains the basilar artery, and is continuous below with the subarachnoid cavity of the medulla spinalis, behind with the cisterna cerebellomedullaris, and in front of the pons with the cisterna interpeduncularis. The *cisterna interpeduncularis* (cisterna basalis) is a wide cavity where the arachnoid extends across between the two temporal lobes. Within it are the cerebral peduncles, the structures in the interpeduncular fossa, and the arterial circle of Willis. Anteriorly, the cisterna interpeduncularis is continuous with the cisterna chiasmatis which lies in front of the optic chiasma and is prolonged on the upper surface of the corpus callosum; here the arachnoid stretches between the cerebral hemispheres immediately beneath the free border of the falx cerebri, and thus leaves a space in which the anterior cerebral arteries are contained. The *cisterna fossæ cerebri lateralis* contains the middle cerebral

artery, and is formed in front of either temporal lobe by the arachnoid bridging the lateral cerebral fissure. The *cisterna venæ magnæ cerebri* occupies the interval between the splenium of the corpus callosum and the superior surface of the cerebellum; it extends between the layers of the tela chorioidea of the third ventricle and contains the great cerebral vein.

FIG. 872.—A diagram showing the positions of the three principal subarachnoid cisternæ.



The subarachnoid cavity communicates with the general ventricular cavity of the brain by three openings: one, the *foramen of Majendie*, is in the middle line at the inferior part of the roof of the fourth ventricle; the other two are at the extremities of the lateral recesses of that ventricle, behind the upper roots of the glossopharyngeal nerves. It is stated by Meckel that the lateral ventricles also communicate with the subarachnoid cavity at the apices of their inferior cornua. There is no direct communication between the subdural and subarachnoid cavities.

The spinal part of the subarachnoid cavity is a wide interval, and is largest at the lower part of the vertebral canal, where the arachnoid encloses the nerves which form the cauda equina. Above, it is continuous with the cranial subarachnoid cavity; below, it ends at the level of the lower border of the second sacral vertebra. It is partially divided by a longitudinal septum, the *subarachnoid septum*, which connects the arachnoid with the pia mater opposite the posterior median sulcus of the medulla spinalis, and forms a partition, incomplete and cribriform above, but more complete in the thoracic region. The spinal subarachnoid cavity is further subdivided by the *ligamentum denticulatum* (p. 885).

The **arachnoideal granulations** (glandulæ Pacchionii) (fig. 873) are small fleshly-looking elevations, usually collected in clusters which are present in the vicinity of the superior sagittal, transverse, and some other sinuses. Upon laying open the sagittal sinus and the venous lacunæ on either side of it, granulations will be found protruding into their interior. On close inspection they may be seen at the age of eighteen months, "and at the age of three they are disseminated over a considerable area"; they increase in number and size as age advances. They are enlarged or distended normal villi of the arachnoid, which cause absorption of the bone, and so produce the pits or depressions on the inner wall of the calvarium.

Structure.—The growth and structure of the arachnoideal granulations have recently been studied by le Gros Clark.* Histologically each granulation appears as a diverticulum of the subarachnoid cavity, penetrating into the interstices of the dura mater, and covered by a layer of flattened cells (arachnoid mesothelium) containing large oval nuclei and lightly staining protoplasm. In the subarachnoid cavity is a reticulum of fine fibrous tissue, the density of which is as a rule greater at the periphery than at the centre of the granulation; in advanced age calcareous nodules are frequently found in it.

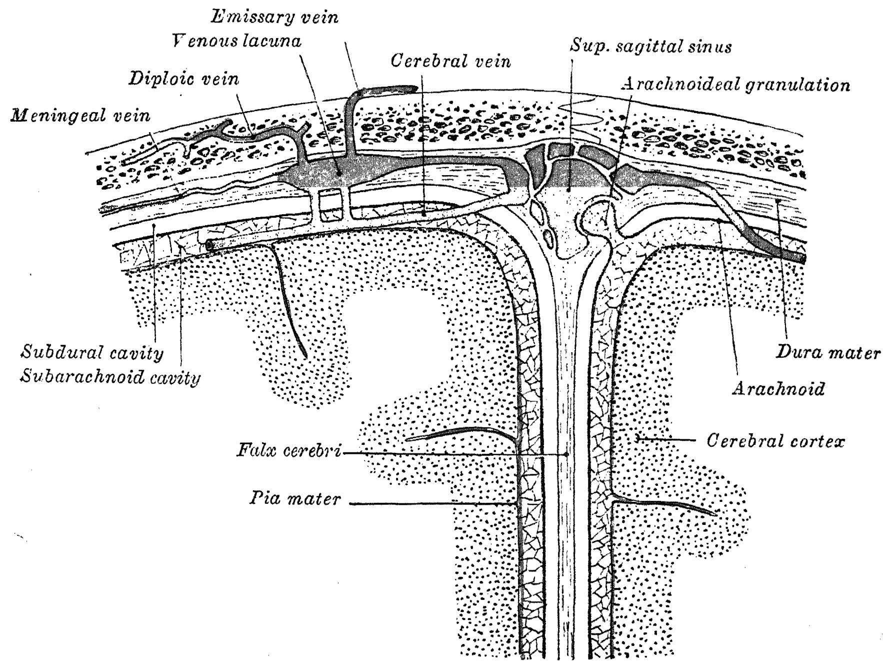
At the summit of the granulation the mesothelial cells proliferate and form a cap which penetrates the surrounding dura mater, and fuses with the endothelial lining of one of the intradural venous sinuses; in doing so it pulls out a little stalk of arachnoid membrane

* W. E. le Gros Clark, *Journal of Anatomy*, vol. lv. 1920.

containing a diverticulum of the subarachnoid cavity. Except at the point of fusion with the endothelial lining of the sinus, the granulation is surrounded by the subdural space and the dura mater; the latter, covered on its cerebral surface by a layer of endothelium, is invaginated into the venous sinus by the protrusion of the granulation.

Fluid injected into the subarachnoid cavity passes into these granulations, and it has been found experimentally that fluid passes by osmosis from the arachnoideal villi into the venous sinuses of the dura mater.

FIG. 873.—A coronal section through the top of the skull, showing the membranes of the brain, &c. Diagrammatic. (Modified from Testut.)



The cerebrospinal fluid is a clear, slightly alkaline fluid, with a specific gravity of about 1007. It contains in solution inorganic salts similar to those in the blood-plasma, and also traces of protein and glucose. It supports and protects the delicate structures of the brain and medulla spinalis, and maintains a uniform pressure on them. The arachnoideal villi are essential structures in the return of the cranial cerebrospinal fluid into the blood-stream (Weed *).

Applied Anatomy.—In various diseases, such as syphilis, meningitis, and infantile paralysis, changes take place in the chemical nature of the substances dissolved in the cerebrospinal fluid, or in the various cells found suspended in it; and these alterations are often of service in diagnosis.

Evidence of great value in the diagnosis of meningitis may sometimes be obtained by puncturing the spinal membranes and withdrawing some of the cerebrospinal fluid; moreover, the operation of lumbar puncture is in many cases curative, possibly because the draining of some of the cerebrospinal fluid relieves the patient by diminishing the intracranial pressure. The operation is performed by inserting a trocar, of the smallest size, between the laminæ of the third and fourth, or of the fourth and fifth lumbar vertebræ, through the ligamentum flavum. The medulla spinalis, even of a child at birth, does not reach below the third lumbar vertebra, and therefore the canal may be punctured between the third and fourth lumbar vertebra without any risk of injuring this structure. The point of puncture is indicated by laying the patient on the side and dropping a perpendicular line from the highest point of the iliac crest; this will cross the upper border of the spinous process of the fourth lumbar vertebra, and will indicate the level at which the trocar should be inserted a little to one side of the middle line. The puncture may require to be repeated more than once, and the greatest precaution must be taken not to allow septic infection of the meninges. If there be any appreciable increase of pressure, the fluid will flow through the trocar with the greatest freedom.

* Lewis H. Weed, Carnegie Institute of Washington; *Contributions to Embryology*, vol. 9, 1920.

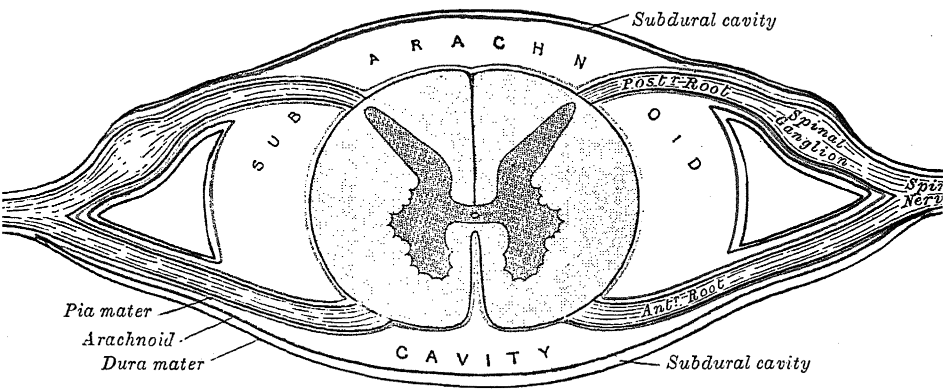
In addition to the constitutional signs and symptoms of fever, *acute spinal meningitis* exhibits certain characteristic features. Pain and tenderness to pressure along the vertebral column are common, and so are pains in the limbs or round the trunk from irritation of the posterior nerve-roots by the inflammatory products. Irritation of the anterior nerve-roots is shown by the increased tone of the muscles, which may go on to the point where they pass into a state of spasm with much-increased reflexes; this is often seen in the retraction of the head and neck. Later in the disease the reflexes are often lost, when, also, the urine and fæces may be passed involuntarily.

Spinal anæsthesia can be induced by injecting certain substances, especially novocain, into the cerebrospinal fluid. It is done by means of a syringe attached to a lumbar puncture needle, and is especially valuable when, from any cause, the administration of a general anæsthetic is inadvisable; but any operation below the level of the umbilicus (10th thoracic nerve) can be performed painlessly by this method.

The Pia Mater

The **pia mater** closely invests the brain and medulla spinalis; it is a vascular membrane, consisting of a minute plexus of blood-vessels held together by an extremely fine areolar tissue. The *cerebral pia mater* invests the entire surface

Fig. 874.—A transverse section through the medulla spinalis and its membranes. Diagrammatic.



of the brain, dips between the cerebral gyri and between the cerebellar laminæ, and is invaginated to form the tela chorioidea of the third ventricle, and the chorioid plexuses of the lateral and third ventricles (pp. 865, 866); as it passes over the roof of the fourth ventricle, it forms the tela chorioidea and the chorioid plexuses of this ventricle (p. 823). Upon the surfaces of the hemispheres it gives off from its deep surface a multitude of sheaths around the minute vessels that run perpendicularly for some distance into the cerebral substance. On the cerebellum the membrane is more delicate; the vessels from its deep surface are shorter, and its relations to the cortex are not so intimate.

The *spinal pia mater* (figs. 871, 874) is thicker, firmer, and less vascular than the cerebral pia mater; this is due to the fact that it consists of two layers, the outer or additional one being composed of bundles of connective tissue fibres, arranged for the most part longitudinally. Between the layers are cleft-like spaces which communicate with the subarachnoid cavity, and a number of blood-vessels. The spinal pia mater covers the medulla spinalis, and is intimately adherent to it; in front it sends a septum into the anterior fissure. A longitudinal fibrous band, called the *linea splendens*, extends along the middle line of the anterior surface, and a somewhat similar band, the *ligamentum denticulatum*, is situated on either side. Below the conus medullaris the pia mater is continued as a long slender filament, the *filum terminale* (p. 785).

The pia mater forms sheaths for the cerebral and spinal nerves; these sheaths are closely connected with the nerves, and blend with their common membranous investments.

The **ligamentum denticulatum** (figs. 871, 901) is a narrow fibrous band situated on either side of the medulla spinalis, and separating the anterior from the posterior nerve-roots. Its medial border is continuous with the pia mater at the side of the medulla spinalis. Its lateral border presents a series of triangular tooth-like processes, the points of which are fixed at intervals to the dura mater. These processes are twenty-one in number, on either side. The first process crosses behind the vertebral artery at the point where that vessel pierces the dura mater, and is separated by the artery from the first cervical nerve; it is attached to the dura mater immediately above the margin of the foramen magnum, 1·25 cm. behind the hypoglossal nerve. The last process is between the exits of the twelfth thoracic and first lumbar nerves, and consists of a narrow oblique band running downwards and lateralwards from the conus medullaris (Parsons *).

THE CEREBRAL NERVES

There are twelve pairs of cerebral nerves, which are named from before backwards as follows:

1st. Olfactory.	5th. Trigeminal.	9th. Glossopharyngeal.
2nd. Optic.	6th. Abducent.	10th. Vagus.
3rd. Oculomotor.	7th. Facial.	11th. Accessory.
4th. Trochlear.	8th. Acoustic.	12th. Hypoglossal.

These nerves are attached to the brain, and are transmitted through openings in the base of the cranium. The **motor** or efferent cerebral nerves arise within the brain from groups of nerve-cells which constitute their *nuclei of origin*. They are brought into relationship with the cerebral cortex by the geniculate fibres of the internal capsule; these fibres arise from the cells of the motor area of the cortex, cross the middle line and end by arborising round the cells of the nuclei of origin of the motor cranial nerves. The **sensory** or afferent cerebral nerves arise from nerve-cells outside the brain; these nerve-cells may be grouped to form ganglia on the trunks of the nerves, or may be situated in peripheral sensory organs such as the nose, eye and ear. The centrally directed processes of the cells run into the brain, and there end by arborising around nerve-cells which are grouped to form *nuclei of termination*. Fibres arise from the cells of these nuclei and, after crossing to the opposite side, join the lemniscus, and thus connect the nuclei, directly or indirectly, with the cerebral cortex.

The Olfactory Nerves (fig. 875)

The **olfactory nerves**, or nerves of smell, are distributed to the mucous membrane of the olfactory region of the nasal cavity; this region comprises the superior nasal concha, and the opposed part of the nasal septum. The nerve-fibres originate from the central or deep processes of the olfactory cells of the nasal mucous membrane, and are collected into bundles which cross one another in various directions, and thus give rise to the appearance of a plexiform network in the mucous membrane. They are then collected into about twenty branches, which pierce the lamina cribrosa of the ethmoidal bone in lateral and medial groups, and end in the glomeruli of the olfactory bulb (fig. 876). Each branch receives tubular sheaths from the dura mater and pia mater, the former being continued into the periosteum of the nose, the latter into the neurolemma of the nerve.

The olfactory nerves are non-medullated, and consist of axis-cylinders surrounded by nucleated sheaths, in which, however, there are fewer nuclei than in the sheaths of ordinary non-medullated nerve-fibres.†

* *Proceedings of the Anatomical Society of Great Britain and Ireland,* 1915.

† Closely associated with the olfactory nerves is a pair of small nerves named the *nervi terminales.*

These nerves were first seen in the lower vertebrates, but their presence has been demonstrated in the human embryo and adult. They consist chiefly of non-medullated nerve-fibres, and on

The olfactory centre in the cortex is generally associated with the rhinencephalon (p. 851).

FIG. 875.—The nerves of the septum of the nose. Right side.

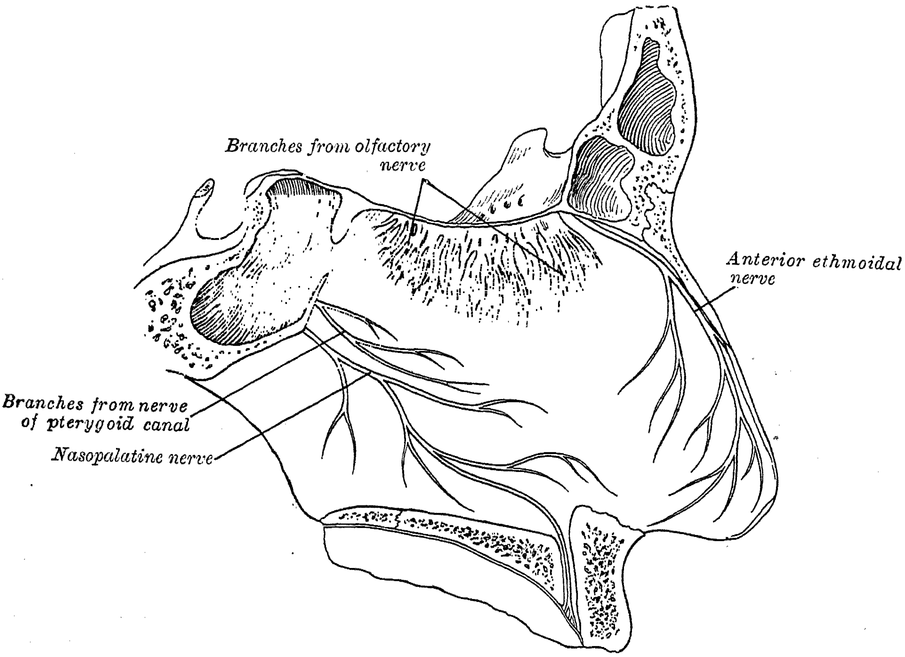
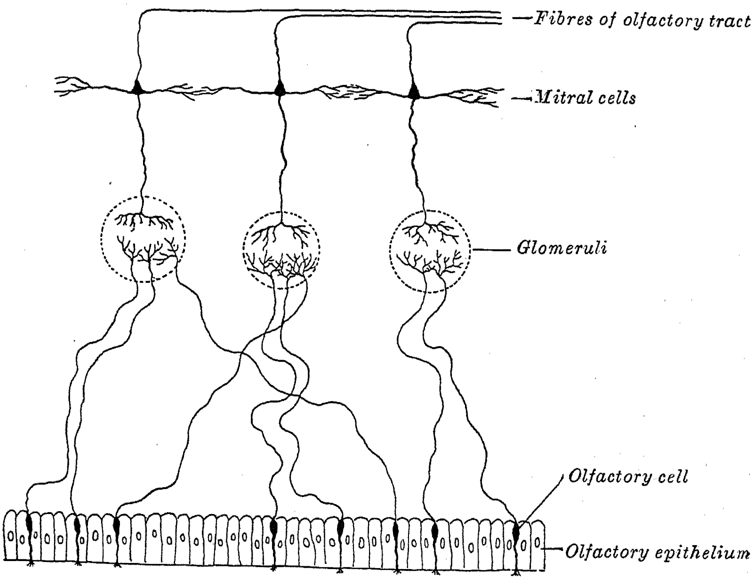


FIG. 876.—A plan of the olfactory neurons.



them there are small groups of bipolar and multipolar nerve-cells. Each nerve runs along the medial side of the corresponding olfactory tract, and its branches traverse the lamina cribrosa of the ethmoidal bone, and are distributed to the nasal mucous membrane. Centrally, the nerve is connected to the brain at the olfactory trigone; in some animals its fibres have been traced to the lamina terminalis; in others to the hypothalamic region. Its function is unknown; some are inclined to view it as a forward extension of the cephalic part of the sympathetic which is distributed to the blood-vessels and glands of the nasal cavity.

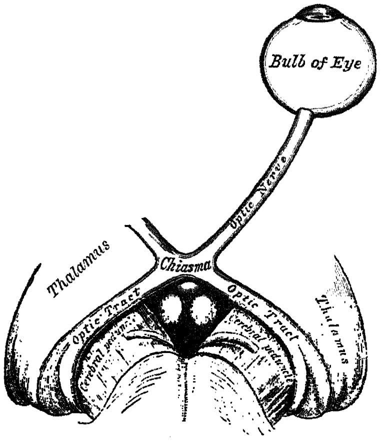
Applied Anatomy.—In severe injuries to the head involving the anterior fossa of the base of the skull, the olfactory bulb may become separated from the olfactory nerves or the nerves may be torn, thus producing loss of smell (*anosmia*), and with this there is a considerable loss in the sense of taste, since much of the perfection of the sense of taste is due to the substances being also odorous, and simultaneously exciting the sense of smell.

Anosmia often occurs after influenza or other acute infection of the nose. Parosmia, or a perversion of the sense of smell, may occur in lesions of the cortical olfactory centres, or in insanity.

The Optic Nerve (fig. 877)

The **optic nerve** or nerve of sight is distributed to the bulb of the eye. Most of its fibres are afferent and originate in the nerve-cells of the ganglionic layer of the retina (p. 1001), but a few are efferent and spring from nerve-cells in the lower visual centres of the brain (p. 836). Developmentally, the optic nerves and the retinæ are parts of the brain (p. 101).

Fig. 877.—The left optic nerve, the optic chiasma, and the optic tracts. Inferior aspect.



The fibres of the optic nerve form the innermost layer (stratum opticum) of the retina; they converge to the optic disc, and then pierce the chorioid coat and the lamina cribrosa of the sclera at the posterior part of the bulb of the eye, about 3 or 4 mm. to the nasal side of its centre. As the nerve-fibres traverse the lamina cribrosa they receive their medullary sheaths, and run in bundles which are collected to form the optic nerve.

The optic nerve, about 4 cm. long, is directed backwards and medialwards through the posterior part of the orbital cavity. It then runs through the optic foramen into the cranial cavity and joins the optic chiasma.

The intra-orbital part of the nerve is about 25 mm. long and has a slightly sinuous course, the length of the nerve being about 6 mm. more than the distance between the optic foramen and the eyeball. Posteriorly it is closely surrounded by the rectus muscles, but anteriorly is separated from them by a quantity of fat in which the ciliary vessels and nerves are lodged. The ciliary ganglion lies between the nerve and the Rectus lateralis muscle. The infero-medial surface of the nerve is pierced, at a distance of about 12 mm. behind the bulb of the eye, by the central artery and vein of the retina, which are then directed forwards in the centre of the nerve to the optic disc. Near the optic foramen the ophthalmic artery runs forwards and medialwards across the nerve; in the foramen the nerve lies above and medial to the artery, and is separated medially from the sphenoidal and posterior ethmoidal air-sinuses by a thin lamina of bone.

The intracranial part of the optic nerve, about 10 mm. long, runs backwards and medialwards from the optic foramen to the optic chiasma. Above it are the posterior parts of the olfactory tract and gyrus rectus, and, near the chiasma, the anterior cerebral artery. On its lateral side is the internal carotid artery.

The optic nerve consists mainly of fine medullated fibres, and is enclosed in three sheaths which are continuous with the membranes of the brain. The *outer sheath*, derived from the dura mater, is thick and fibrous, and blends anteriorly with the sclera of the bulb of the eye. The *intermediate sheath*, derived from the arachnoid membrane, is thin and delicate. It is separated from the outer sheath by the subdural space, and from the inner sheath by the subarachnoid cavity. The *inner sheath*, derived from the pia mater, is vascular and closely invests the nerve. From its deep surface septa pass into the nerve and subdivide and reunite to enclose what appear, in transverse sections of the nerve, as polygonal areas which are occupied by the bundles of nerve-fibres. From the inner sheath also, an investment is carried on the central vessels of the retina as far as the optic disc.

an opening, the hilum, from which most of the fibres of the brachium conjunctivum emerge (p. 818).

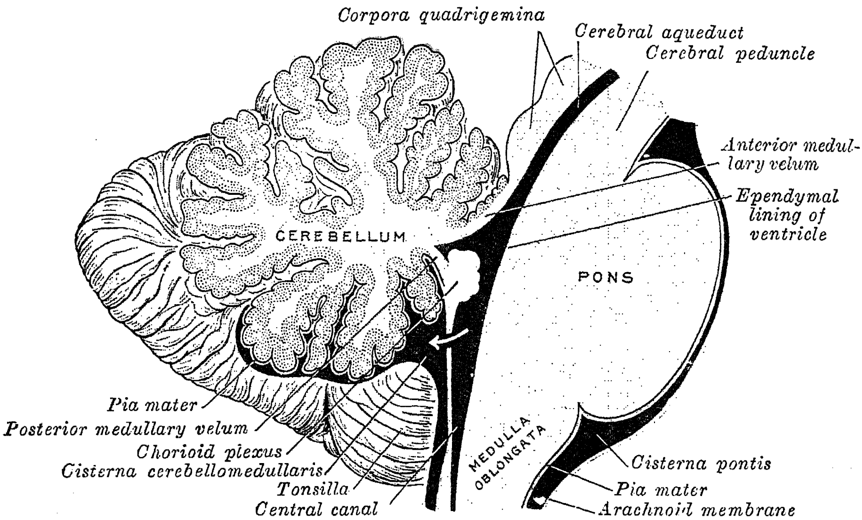
The *nucleus emboliformis* lies close to the medial side of the nucleus dentatus, and partly covering its hilum. The *nucleus globosus*, an elongated mass, lies on the medial side of the nucleus emboliformis, and is directed anteroposteriorly. The *nucleus fastigii* (nucleus tecti), somewhat larger than the other two, is situated close to the middle line in the anterior part of the superior vermis, and immediately over the roof of the fourth ventricle, from which it is separated by a thin layer of white substance.

Applied Anatomy.—The general functions of the cerebellum in the human economy appear to be the co-ordination of movements, and equilibration. The exact functions of its different parts are still quite uncertain, owing to the contradictory nature of the evidence furnished by (1) ablation experiments upon animals, and (2) clinical observations in man of the effects produced by abscesses or tumours affecting different portions of the organ. According to W. Aldren Turner, 'The following localising symptoms would therefore indicate the presence of a tumour implicating the right cerebellar hemisphere and middle peduncle: deafness in the right ear, unassociated with middle ear complications and unsteady and uncertain gait with a tendency to fall more particularly to the right side; coarse nystagmoid oscillations on looking to the right; movements resembling those of disseminated sclerosis on volitional effort of the right arm; an awkward uncertain action of the right leg; a slight increase of the right knee-jerk; and, perhaps, slight blunting of sensibility over the right cornea and side of the face.'

The Fourth Ventricle

The **fourth ventricle**, or cavity of the rhombencephalon, is a somewhat lozenge-shaped space situated in front of the cerebellum, and behind the pons and upper half of the medulla oblongata. Developmentally considered, it

Fig. 820.—A scheme showing the roof of the fourth ventricle. The arrow is in the foramen of Majendie.



consists of three parts: a *superior* belonging to the isthmus rhombencephali, an *intermediate*, to the metencephalon, and an *inferior*, to the myelencephalon. It is lined by ciliated epithelium, and its inferior angle is continuous with the central canal of the medulla oblongata; its superior angle is continuous with the cerebral aqueduct which opens above into the cavity of the third ventricle. From its middle part a narrow, curved pouch, named the *lateral recess*, is prolonged on either side between the restiform body and the flocculus, and reaches as far as the attachments of the glossopharyngeal and vagus nerves.

The fourth ventricle possesses lateral boundaries, a roof or dorsal wall, and a floor or ventral wall (rhomboid fossa).

The **optic tract** is a cylindrical bundle of nerve-fibres which runs backwards and lateralwards from the optic chiasma. It passes between the anterior perforated substance and the tuber cinereum and reaches the under surface of the cerebral peduncle, where it becomes flattened. It then winds round and is adherent to the cerebral peduncle, and divides into a medial and a lateral root. The fibres of the medial root form the commissure of Gudden, already referred to; the lateral and larger root ends in the lateral geniculate body, the pulvinar of the thalamus and the superior colliculus (superior quadrigeminal body), which together constitute the *lower visual centres*. From the cells of the lateral geniculate body and the pulvinar fibres, termed the *optic radiations*, take origin, and pass through the occipital part of the internal capsule to the *higher or cortical visual centre*, which is situated in the cuneus and in the neighbourhood of the calcarine fissure. Many efferent fibres from the superior colliculus cross the middle line and descend in the medial longitudinal fasciculus, some ending in the nuclei of the oculomotor, trochlear and abducent nerves, others (tectospinal fibres) passing to the spinal medulla.

Applied Anatomy.—The optic nerve is peculiarly liable to become the seat of neuritis or undergo atrophy in affections of the central nervous system, and as a rule the pathological relationship between the two affections is exceedingly difficult to trace. There are, however, certain points in connexion with the anatomy of this nerve which tend to throw light upon the frequent association of its affections with intracranial disease. (1) From its mode of development, and from its structure, the optic nerve must be regarded as a prolongation of the brain-substance, rather than as an ordinary cerebral nerve. (2) It receives sheaths from the three cerebral membranes, and these sheaths are separated from each other by spaces which communicate with the subdural and subarachnoid cavities respectively. The innermost sheath sends a process around the arteria centralis retinæ into the interior of the nerve, and enters intimately into its structure. Thus inflammatory affections of the meninges or of the brain may readily extend along these spaces, or along the interstitial connective tissue in the nerve.

The optic neuritis or papillitis ("choked disc") that is often seen in cases of intracranial new growth with increased intracranial tension is probably caused by increased pressure in the sheath of the optic nerve, due to excess of fluid in the general subarachnoid space with which this sheath is in direct communication. If, as is the case, for example in the internal hydrocephalus seen as a complication of cerebro-spinal fever, there is no increase in the amount of fluid in the subarachnoid space, then there will be no optic neuritis although the intracranial tension may rise until it brings about the patient's death.

The course of the fibres in the optic chiasma has an important pathological bearing and has been the subject of much controversy. Microscopic examination, experiments, and pathology all seem to point to the fact that there is a partial decussation of the fibres, each optic tract supplying the corresponding half of each eye, so that the right tract supplies the right half of each eye, and the left tract the left half of each eye. At the same time Charcot believes, and his view has met with general acceptance, that the fibres which do not decussate at the optic chiasma undergo decussation in the corpora quadrigemina, so that the lesion of the cerebral centre of one side causes complete blindness of the opposite eye, because both sets of decussating fibres are destroyed; whereas if one tract, say the right, be destroyed by disease, there will be blindness of the right half of both retinæ.

An anteroposterior section through the chiasma would divide the decussating fibres, and would therefore produce blindness of the medial half of each eye; while a section at the margin of the side of the optic chiasma would produce blindness of the lateral half of the retina of the same side. An early symptom of tumour-growth in the hypophysis is pressure on the chiasma.

The optic nerve may also be affected in injuries or diseases involving the orbit; in fractures of the anterior fossa of the base of the skull; in tumours of the orbit itself, or those invading this cavity from neighbouring parts.

The Oculomotor Nerve (figs. 880 to 882)

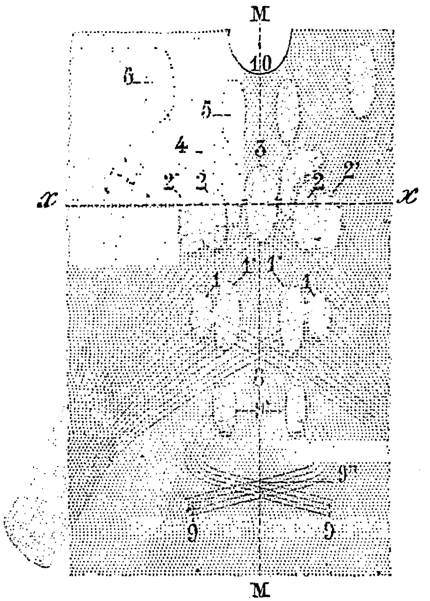
The **oculomotor nerve** supplies all the ocular muscles, except the Obliquus superior and Rectus lateralis; it also supplies, through its connexion with the ciliary ganglion, the Sphincter pupillæ and the Ciliaris muscles.

The fibres of the oculomotor nerve arise from a nucleus which lies in the grey substance of the upper part of the floor of the cerebral aqueduct and extends in front of the aqueduct for a short distance into the floor of the third ventricle. From this nucleus the fibres pass forwards through the tegmentum, the red nucleus, and the medial part of the substantia nigra, forming a series

of curves with a lateral convexity, and emerge from the oculomotor sulcus on the medial side of the cerebral peduncle (fig. 822).

The nucleus of the oculomotor nerve does not consist of a continuous column of cells, but is broken up into a number of smaller nuclei, which are arranged in two groups, anterior and posterior. Those of the posterior group are six in number, five of which are symmetrical on the two sides of the middle line, while the sixth is centrally placed and is common to the nerves of both sides. The anterior group consists of two nuclei, an anteromedial and an anterolateral (fig. 879).

FIG. 879.—A scheme showing the different groups of cells which constitute, according to Perlia, the nucleus of origin of the oculomotor and trochlear nerves. (Testut.)



1. Posterior dorsal nucleus. 1′. Posterior ventral nucleus. 2. Anterior dorsal nucleus. 2′. Anterior ventral nucleus. 3. Central nucleus. 4. Nucleus of Edinger and Westphal. 5. Anteromedial nucleus. 6. Anterolateral nucleus. 8. Crossed fibres. 9. Trochlear nerve, with 9′, its nucleus of origin, and 9″, its decussation. 10. Third ventricle. M, M. Median line.

The nucleus of the nerve is said to send fibres through the medial longitudinal fasciculus to the facial nerve, for the supply of the Orbicularis oculi, Corrugator, and Frontalis muscles.* It is also connected with the nuclei of the trochlear and abducent nerves, with the cerebellum, the superior colliculus, and the cortex of the occipital lobe of the cerebrum.

The nucleus of the oculomotor nerve, considered from a physiological standpoint, can be subdivided into several smaller groups of cells, each group controlling a particular muscle. The nerves to the different muscles appear to take their origin from behind forwards as follows: Rectus inferior, Obliquus inferior, Rectus medialis, Rectus superior, and Levator palpebræ superioris; while from the anterior end of the nucleus the fibres for the Ciliaris, and possibly those for the Sphincter pupillæ, take their origin. Some observers are of opinion that the fibres which supply the Sphincter pupillæ are not derived from the nucleus of the third nerve.†

On emerging from the brain, the nerve is invested with a sheath of pia mater, and enclosed in a prolongation from the arachnoid. It passes between the superior cerebellar and posterior cerebral arteries, runs forward in the cisterna interpeduncularis on the lateral side of the posterior communicating artery. It then perforates the arachnoid membrane and lies in the triangular interval between the free and attached borders of the tentorium cerebelli. Piercing the dura mater on the lateral side of the posterior clinoid process the nerve traverses the lateral wall of the cavernous sinus, where it lies above the trochlear nerve, and receives one or two filaments from the cavernous plexus of the sympathetic, and a branch from the ophthalmic division of the trigeminal. It then divides into a superior and an inferior ramus, which enter the orbit through the superior orbital fissure, within the annulus tendineus which gives origin to the Recti muscles; here the nasociliary nerve is placed between the two rami.

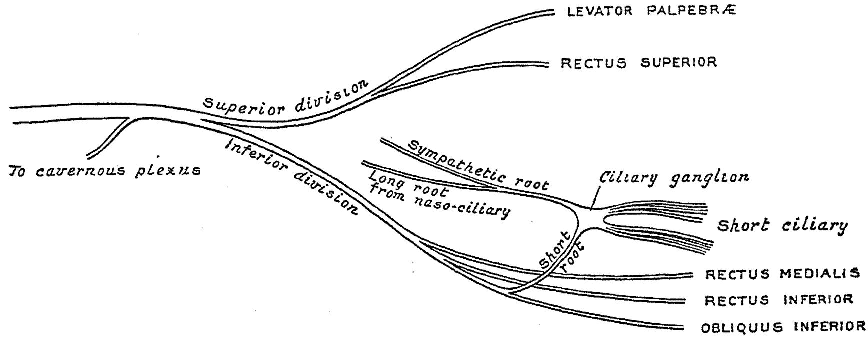
The *superior ramus*, the smaller, ascends on the lateral side of the optic nerve, and supplies the Rectus superior and Levator palpebræ superioris. The *inferior ramus* divides into three branches (fig. 880). One passes beneath the optic nerve to the Rectus medialis; another goes to the Rectus inferior; the third and longest runs forwards between the Rectus inferior and Rectus lateralis,

* See footnote, p. 828.

† Consult an article on 'Ocular palsies' by Leslie Paton, *British Journal of Ophthalmology*, vol. v. No. 6, June, 1921.

to the Obliquus inferior. From the nerve to the Obliquus inferior a short thick branch is given to the lower part of the ciliary ganglion, and forms its *short* or *parasympathetic root*. The branches enter the muscles on their ocular surfaces, with the exception of that to the Obliquus inferior, which enters the posterior border of the muscle.

Fig. 880.—A plan of the oculomotor nerve.



Applied Anatomy.—Paralysis of the oculomotor nerve may be the result of various causes, such as cerebral disease; or conditions causing pressure on the cavernous sinus; or periostitis of the bones entering into the formation of the superior orbital fissure. It leads, when complete, to (1) ptosis, or drooping of the upper eyelid, in consequence of the Levator palpebræ superioris being paralysed; (2) external strabismus, on account of the unopposed action of the Rectus lateralis and Obliquus superior, which are not supplied by the oculomotor nerve and are therefore not paralysed; (3) dilatation of the pupil, because the Sphincter pupillæ is paralysed; (4) loss of power of accommodation and of contraction on exposure to light, as the Sphincter pupillæ and the Ciliaris are paralysed; (5) slight prominence of the eyeball, owing to most of its muscles being relaxed; and (6) diplopia, or double vision, the false image being higher than the true, and the separation of the two images increasing with medial movements. Occasionally paralysis may affect only a part of the nerve—that is to say, there may be, for example, a dilated and fixed pupil, with ptosis, but no other signs. Irritation of the nerve causes spasm of one or other of the muscles supplied by it; thus, there may be internal strabismus from spasm of the Rectus medialis; accommodation for near objects only, from spasm of the Ciliaris; or miosis (contraction of the pupil) from irritation of the Sphincter pupillæ.

The oculomotor nerve is particularly liable to become involved in a syphilitic periarteritis, as it leaves the base of the brain, when passing between the posterior cerebral and superior cerebellar arteries.

The Trochlear Nerve (fig. 881)

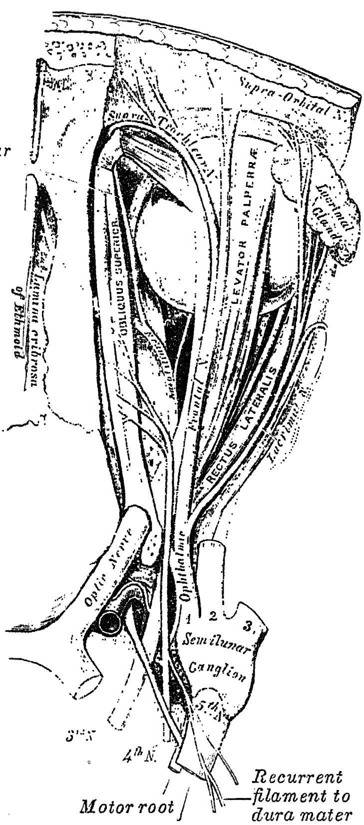
The **trochlear nerve**, the smallest of the cerebral nerves, supplies the Obliquus superior oculi.

It arises from a nucleus situated in the floor of the cerebral aqueduct, opposite the upper part of the inferior colliculus. From its origin it runs downwards through the tegmentum, and then turns backwards into the upper part of the anterior medullary velum. Here it decussates with its fellow, and reaching the opposite side, emerges from the surface of the velum at the side of the frenulum veli, immediately behind the inferior colliculus.

The nerve is directed across the brachium conjunctivum cerebelli, and then winds forwards round the cerebral peduncle immediately above the pons, and between the posterior cerebral and superior cerebellar arteries. It appears between the border of the pons and the temporal lobe, and pierces the dura mater immediately below the free border of the tentorium cerebelli, a little behind the posterior clinoid process, and passes forwards in the lateral wall of the cavernous sinus, below the oculomotor nerve and above the ophthalmic division of the trigeminal nerve. Near the front of the sinus it crosses the oculomotor nerve, and enters the orbit through the superior orbital fissure, above the ocular muscles, and medial to the frontal nerve. In the orbit it passes medialwards, above the origin of the Levator palpebræ superioris, and finally enters the orbital surface of the Obliquus superior.

In the lateral wall of the cavernous sinus the trochlear nerve is joined by a branch from the ophthalmic division of the trigeminal nerve, and communicates with the cavernous plexus of the sympathetic. In the superior orbital fissure it occasionally gives off a branch to the lacrimal nerve.

FIG. 881.—The nerves of the right orbit. Superior aspect.



Applied Anatomy.—When the trochlear nerve is paralysed there is loss of function in the Obliquus superior, so that the patient is unable to turn his eye downwards and outwards. Should the patient attempt to do this, the eye of the affected side is rotated inwards, producing diplopia or double vision. Single vision exists in the whole of the field so long as the eyes look above the horizontal plane, diplopia occurs on looking downwards. To counteract this the patient holds his head forwards, and also inclines it to the sound side.

THE TRIGEMINAL NERVE

The **trigeminal nerve** is the largest cerebral nerve. It is the sensory nerve of the face and of the greater part of the scalp, and the motor nerve of the muscles of mastication. It divides into three nerves, viz. the ophthalmic, the maxillary, and the mandibular.

It is attached to the anterior or ventral surface of the pons, near its upper border, by a large sensory, and a small motor, root—the latter being placed medial and anterior to the former.

The fibres of the *sensory root* arise from the cells of the *semilunar ganglion* (Gasserian ganglion). This ganglion (figs. 881, 882) occupies a cavity (cavum Meckelii) in the dura mater covering the trigeminal impression near the apex of the petrous part of the temporal bone. The ganglion is somewhat crescentic in shape, with its convexity directed forwards and lateralwards. Medially, it is in relation with the internal carotid artery and the posterior part of the cavernous sinus. Beneath it are the motor root of the nerve, and the greater superficial petrosal nerve. It receives filaments from the cavernous plexus of the sympathetic, and gives twigs to the tentorium cerebelli.

The axis-cylinders of the cells of the semilunar ganglion divide into peripheral and central branches. The former are grouped to form the *ophthalmic* and *maxillary* nerves, and the sensory part of the *mandibular* nerve. The central branches constitute the fibres of the sensory root of the nerve, which leaves the concave margin of the ganglion, runs backwards and medialwards below the superior petrosal sinus and the tentorium cerebelli, and enters the pons. In the pons these fibres divide into ascending and descending branches. The ascending branches end in the upper sensory nucleus of the trigeminal nerve, which is situated in the pons, lateral to, and somewhat deeper than, the motor nucleus. The descending branches form what is named the *spinal tract* of the trigeminal nerve. This tract runs downwards through the pons into the medulla oblongata superficial to a nucleus of grey substance which is continuous inferiorly with the gelatinous substance of Rolando. As the tract descends, a succession of fibres leaves it and enters the nucleus, and the tract gradually diminishes in size, and finally ends in the upper part of the cervical portion of the medulla spinalis.

Medullation of the fibres of the sensory root begins about the fifth month of fœtal life, but all of its fibres are not medullated until the third month after birth.

The fibres of the *motor root* arise from two nuclei, an inferior and a superior. The *inferior or chief nucleus* is situated in the upper part of the pons, close to its dorsal surface, and along the line of the lateral margin of the rhomboid fossa. The *superior nucleus* consists of a strand of cells occupying the whole length of the lateral portion of the grey substance of the cerebral aqueduct. The fibres from this nucleus constitute the *mesencephalic root* *; they descend through the mesencephalon, and, entering the pons, join with the fibres from the lower nucleus, and the motor root, thus formed, passes forwards through the pons to its point of emergence.

Four small ganglia are associated with the three divisions of the trigeminal nerve, viz.—the *ciliary ganglion* with the ophthalmic nerve ; the *sphenopalatine ganglion* with the maxillary nerve ; and the *otic* and *submaxillary ganglia* with the mandibular nerve.

The Ophthalmic Nerve (figs. 881, 882)

The **ophthalmic nerve**, the first division of the trigeminal nerve, is a sensory nerve. It supplies branches to the bulb of the eye, the lacrimal gland and the conjunctiva, to a part of the mucous membrane of the nasal cavity, and to the skin of the nose, eyelids, forehead, and scalp. It is the smallest division of the trigeminal nerve, and arises from the anteromedial part of the semilunar ganglion as a flattened band, about 2·5 cm. long, which passes forwards along the lateral wall of the cavernous sinus below the oculomotor and trochlear nerves ; just before entering the orbit through the superior orbital fissure, it divides into three branches, *lacrimal*, *frontal*, and *nasociliary*.

The ophthalmic nerve is joined by filaments from the cavernous plexus of the sympathetic, and gives twigs to the oculomotor, trochlear, and abducent nerves ; it supplies a recurrent branch (n. tentorii), which crosses and adheres to the trochlear nerve, and is distributed to the tentorium cerebelli.

The **lacrimal nerve** (fig. 881) is the smallest branch of the ophthalmic nerve. It sometimes receives a filament from the trochlear nerve, but possibly this filament consists of fibres which have previously passed from the ophthalmic to the trochlear nerve. The lacrimal nerve enters the orbit through the lateral part of the superior orbital fissure, runs along the upper border of the Rectus lateralis with the lacrimal artery, and sends downwards a branch to join the zygomatic branch of the maxillary nerve. It enters the lacrimal gland and gives off several filaments to the gland and the conjunctiva. Finally it pierces the orbital septum, and ends in the skin of the upper eyelid, joining with filaments of the facial nerve.

The lacrimal nerve is occasionally absent, and its place is then taken by the zygomaticotemporal branch of the maxillary nerve. Sometimes the latter branch is absent, and a continuation of the lacrimal is substituted for it.

The **frontal nerve** (figs. 881, 882) is the largest branch of the ophthalmic nerve. It enters the orbit through the superior orbital fissure above the muscles, and runs forwards between the Levator palpebræ superioris and the periosteum. About midway between the apex and base of the orbit it divides into two branches, a small supratrochlear and a larger supra-orbital.

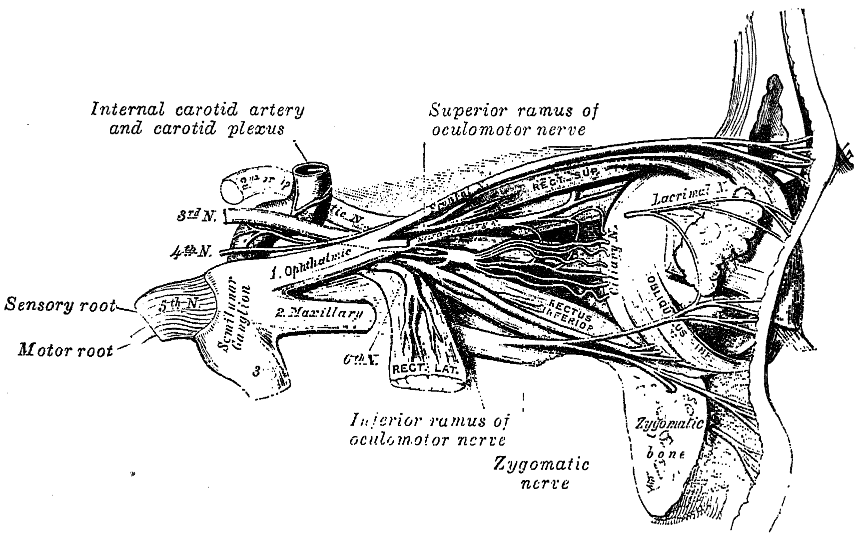
The *supratrochlear nerve* runs medialwards and forwards, passes above the pulley of the Obliquus superior, and gives off a descending filament, to join the infratrochlear branch of the nasociliary nerve. The nerve then emerges from the orbit between the pulley of the Obliquus superior and the supra-orbital foramen, curves upwards on the forehead close to the bone in company with the frontal branch of the ophthalmic artery, and sends filaments to the conjunctiva and skin of the upper eyelid ; it then ascends under cover of the Corrugator and Frontalis, and divides into branches which pierce these muscles and supply the skin of the lower part of the forehead close to the middle line.

* Some are of opinion that the mesencephalic root of the trigeminal nerve consists of sensory fibres.

The *supra-orbital nerve* passes through the supra-orbital foramen, and gives off palpebral filaments to the upper eyelid. It then ascends upon the forehead with the supra-orbital artery, and divides into a smaller medial, and a larger lateral, branch, which supply the skin of the scalp, reaching nearly as far back as the lambdoid suture. These two branches are at first situated beneath the Frontalis; the medial branch perforates this muscle, the lateral branch pierces the galea aponeurotica. Both branches supply small twigs to the pericranium and to the mucous membrane of the frontal air-sinus.

The **nasociliary nerve** (figs. 881, 882) is intermediate in size between the frontal and lacrimal nerves, and is more deeply placed. It enters the orbit through the medial part of the superior orbital fissure within the annulus tendineus which gives origin to the Recti muscles of the eyeball, and here it is situated between the two rami of the oculomotor nerve. It crosses the optic nerve with the ophthalmic artery, and runs obliquely beneath the Rectus superior and Obliquus superior, to the medial wall of the orbital cavity. Here, under the name of the *anterior ethmoidal nerve* it passes through the anterior

Fig. 882.—The nerves of the right orbit, and the ciliary ganglion. Lateral aspect.



ethmoidal foramen and, entering the cavity of the cranium, traverses a shallow groove on the lateral margin of the front part of the lamina cribrosa of the ethmoidal bone, beneath the dura mater; it then descends through a slit at the side of the crista galli into the nasal cavity, and lies in a groove on the inner surface of the nasal bone. It supplies two *internal nasal branches*—a medial to the mucous membrane of the front part of the nasal septum, and a lateral to the anterior part of the lateral wall of the nasal cavity. Finally, it emerges, as the *external nasal branch*, between the lower border of the nasal bone and the lateral nasal cartilage, and, passing down beneath the Nasalis muscle, supplies the skin of the ala and apex of the nose.

The nasociliary nerve gives off the long root of the ciliary ganglion, the long ciliary, the infratrochlear, and the posterior ethmoidal nerves.

The *long* or *sensory root of the ciliary ganglion* usually arises from the nasociliary nerve as the latter enters the orbital cavity. It passes forwards on the lateral side of the optic nerve, and enters the posterosuperior angle of the ciliary ganglion; it is sometimes joined by a filament from the cavernous plexus of the sympathetic, or from the superior ramus of the oculomotor nerve.

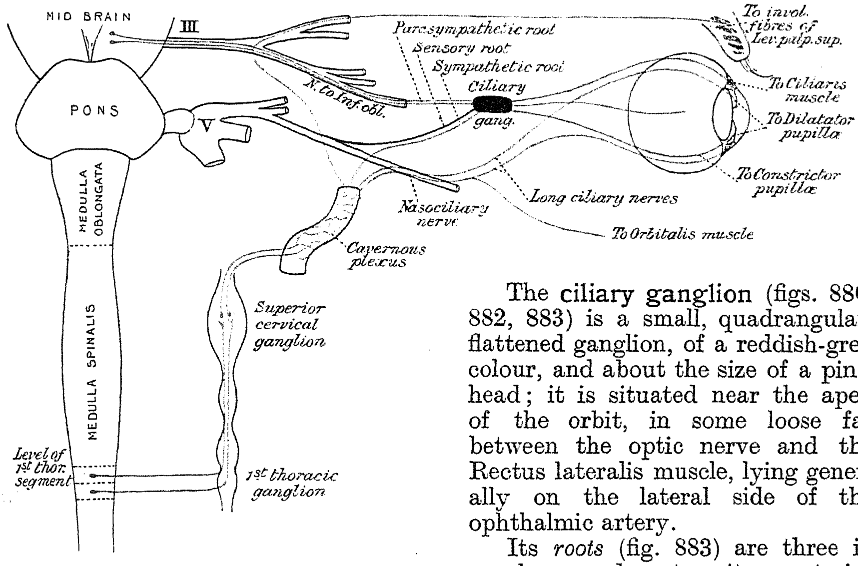
The *long ciliary nerves*, two or three in number, are given off from the nasociliary nerve, as it crosses the optic nerve. They accompany the short ciliary nerves from the ciliary ganglion, pierce the sclera around the attachment of the optic nerve, and, running forwards between the sclera and the chorioid, are

distributed to the ciliary body, iris, and cornea; they contain the sympathetic fibres for the Dilatator pupillæ.

The *infratrochlear nerve* is given off from the nasociliary nerve near the anterior ethmoidal foramen. It runs forwards along the medial wall of the orbit above the upper border of the Rectus medialis, and is joined, near the pulley of the Obliquus superior, by a filament from the supratrochlear nerve. It then escapes from the orbit beneath the pulley of the Obliquus superior; it supplies branches to the skin of the eyelids and side of the nose, the conjunctiva, lacrimal sac, and caruncula lacrimalis.

The *posterior ethmoidal nerve* leaves the orbital cavity through the posterior ethmoidal foramen and gives twigs to the ethmoidal and sphenoidal air-sinuses. This nerve is absent in about thirty per cent. of subjects.

FIG. 883.—A scheme showing the roots and the branches of distribution of the ciliary ganglion.



The **ciliary ganglion** (figs. 880 882, 883) is a small, quadrangular, flattened ganglion, of a reddish-grey colour, and about the size of a pin's head; it is situated near the apex of the orbit, in some loose fat between the optic nerve and the Rectus lateralis muscle, lying generally on the lateral side of the ophthalmic artery.

Its *roots* (fig. 883) are three in number, and enter its posterior border. One, the long or sensory root, is derived from the nasociliary nerve, and joins the posterosuperior angle of the ganglion. The second, the short or parasympathetic root, is a thick nerve (occasionally divided into two parts) derived from the branch of the oculomotor nerve to the Obliquus inferior, and connected with the postero-inferior angle of the ganglion. The third, the sympathetic root, is a slender filament from the cavernous plexus of the sympathetic; it is frequently blended with the long root.

Its *branches* are the short ciliary nerves. These are delicate filaments, from six to ten in number, which arise from the front of the ganglion in two bundles connected with its superior and inferior angles; the lower bundle is the larger. They run forwards with the ciliary arteries in a wavy course, one set above, the other below the optic nerve, and are accompanied by the long ciliary nerves. They subdivide into about fifteen or twenty branches which pierce the sclera around the entrance of the optic nerve, pass forwards in delicate grooves on the inner surface of the sclera, and are distributed to the Ciliaris muscle, iris, and cornea. Tiedemann described a small branch which penetrated the optic nerve with the arteria centralis retinæ.

THE MAXILLARY NERVE (fig. 884)

The **maxillary nerve**, or second division of the trigeminal nerve, is a sensory nerve, and is intermediate in position and size between the ophthalmic and mandibular nerves. It begins at the middle of the semilunar ganglion

as a flattened plexiform band, and, passing horizontally forwards in the lower part of the lateral wall of the cavernous sinus, leaves the skull through the foramen rotundum, where it becomes more cylindrical in form and firmer in texture. It then crosses the upper part of the pterygopalatine (spheno-maxillary) fossa, inclines lateralwards on the posterior surface of the orbital process of the palatine bone and on the upper part of the infratemporal surface of the maxilla, and enters the orbit through the inferior orbital fissure; it traverses the infra-orbital groove and canal in the floor of the orbit, and appears on the face through the infra-orbital foramen.* At its termination, the nerve lies beneath the Quadratus labii superioris, and divides into branches which are distributed to the side of the nose, the lower eyelid, and the upper lip, and join with filaments of the facial nerve.

The *branches* of the maxillary nerve may be divided into four groups, according as they are given off in the cranium, in the pterygopalatine fossa, in the infra-orbital canal, or on the face.

In the cranium . . .	Middle meningeal.
In the pterygopalatine fossa .	Zygomatic. Sphenopalatine. Posterior superior alveolar.
In the infra-orbital canal .	Middle superior alveolar. Anterior superior alveolar.
On the face	Inferior palpebral. External nasal. Superior labial.

The **middle meningeal nerve** is given off from the maxillary nerve near the semilunar ganglion; it accompanies the anterior branch of the middle meningeal artery and supplies the dura mater.

The **zygomatic nerve** (temporomalar nerve) (fig. 882) arises in the pterygopalatine fossa, enters the orbit by the inferior orbital fissure, courses along the lateral wall of the orbit, and divides into two branches, zygomaticotemporal and zygomaticofacial.

The *zygomaticotemporal branch* runs along the lateral wall of the orbit in a groove in the zygomatic bone, receives a branch from the lacrimal nerve, and, passing through a canal in the zygomatic bone, enters the temporal fossa. It ascends between the temporal bone and the Temporalis muscle, pierces the temporal fascia about 2 cm. above the zygomatic arch, and is distributed to the skin of the side of the forehead. It communicates with the facial nerve and with the auriculotemporal branch of the mandibular nerve. As it pierces the temporal fascia, it sends a slender twig between the two layers of the fascia to the lateral angle of the orbit.

The *zygomaticofacial branch* passes along the inferolateral angle of the orbit, emerges upon the face through a foramen in the zygomatic bone, and, perforating the Orbicularis oculi, supplies the skin on the prominence of the cheek. It joins the zygomatic branches of the facial nerve and the inferior palpebral branches of the maxillary nerve.

The **sphenopalatine branches**, two in number, descend towards the sphenopalatine ganglion, but only a few of their fibres enter the ganglion (p. 898).

The **posterior superior alveolar branches** (fig. 884) arise from the maxillary nerve just before it enters the infra-orbital groove; they are generally two in number, but sometimes they arise by a single trunk. They descend on the tuberosity of the maxilla and give off several twigs to the gums and neighbouring parts of the mucous membrane of the cheek. They then enter the posterior alveolar canals on the infratemporal surface of the maxilla, and, passing forwards in the substance of the bone, communicate with the middle superior alveolar nerve, and give off branches to the lining membrane of the maxillary air-sinus and twigs to each molar tooth; these twigs enter the foramina at the apices of the roots of the teeth.

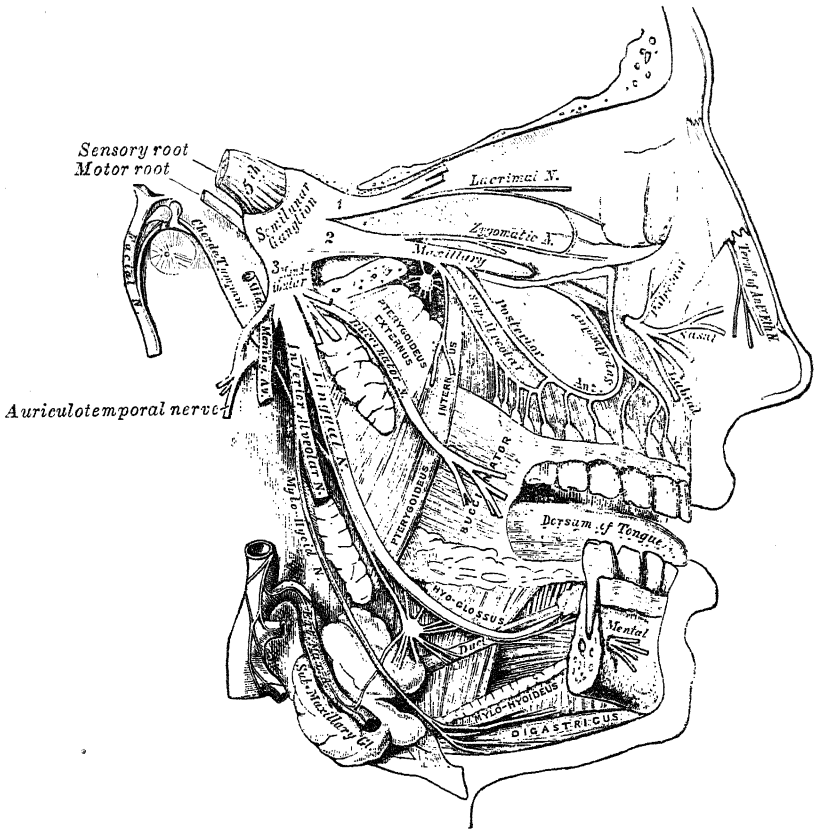
The **middle superior alveolar branch** is given off from the maxillary nerve in the posterior part of the infra-orbital canal, and runs downwards and

* After it enters the infra-orbital canal, the nerve is frequently called the *infra-orbital*.

forwards in a canal in the lateral wall of the maxillary air-sinus to supply the two premolar teeth. It forms a superior dental plexus with the anterior and posterior superior alveolar branches.

The **anterior superior alveolar branch** (fig. 884) leaves the lateral side of the maxillary nerve in the front part of the infra-orbital canal, and runs in a canal in the anterior wall of the maxillary air-sinus. At first it curves beneath the infra-orbital foramen and passes medialwards towards the nose; it then turns downwards and divides into branches which supply the incisor and canine teeth. It communicates with the middle superior alveolar branch, and gives off a *nasal branch*, which passes through a minute canal in the lateral wall of

FIG. 884.—The right maxillary and mandibular nerves, and the submaxillary ganglion.



the inferior meatus, and supplies the mucous membrane of the anterior part of the inferior meatus and the floor of the nasal cavity, communicating with the nasal branches from the sphenopalatine ganglion.

The **inferior palpebral branches** ascend behind the Orbicularis oculi. They supply the skin and conjunctiva of the lower eyelid, and join with the facial and zygomaticofacial nerves at the lateral angle of the orbit.

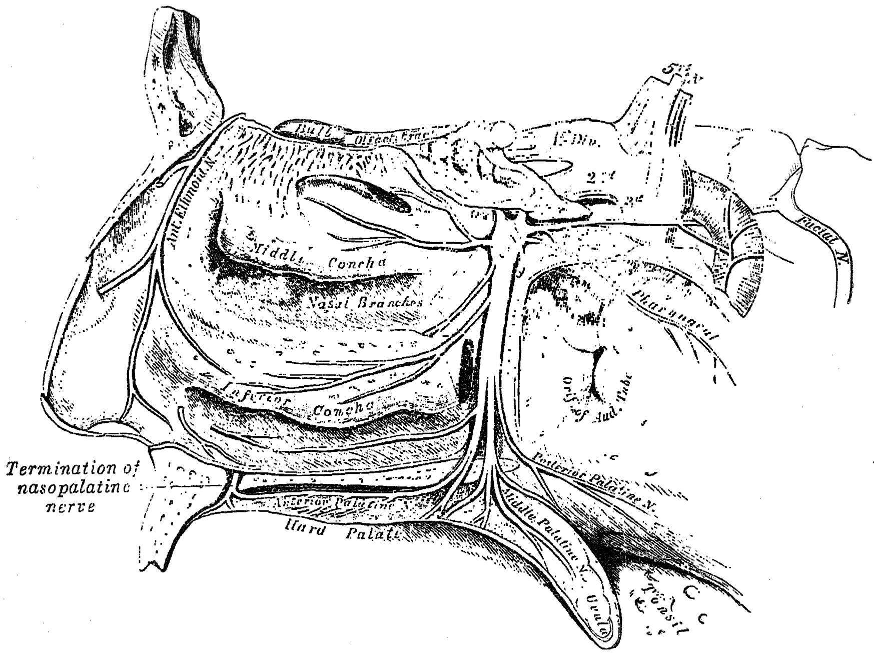
The **external nasal branches** supply the skin of the side of the nose and of the septum mobile nasi, and join with the external nasal branch of the anterior ethmoidal nerve.

The **superior labial branches** are large and numerous; they descend behind the Quadratus labii superioris, and supply the skin of the upper lip, the mucous membrane of the mouth, and the labial glands. They are joined by branches from the facial nerve, and form with them the *infra-orbital plexus*.

The **sphenopalatine ganglion** (ganglion of Meckel) (fig. 885), the largest of the ganglia associated with the branches of the trigeminal nerve, is deeply placed in the pterygopalatine fossa, close to the sphenopalatine foramen and in front of the pterygoid canal. It is triangular or heart-shaped, of a reddish-grey colour, and is situated just below the maxillary nerve as it crosses the fossa. It receives sensory, parasympathetic, and sympathetic roots (fig. 886).

Its *sensory roots* are derived from the two sphenopalatine branches of the maxillary nerve; most of the fibres of these branches do not enter the ganglion but pass directly into the branches which spring from the ganglion. Its *parasympathetic root* is probably derived from the facial nerve through the greater superficial petrosal nerve, and its *sympathetic root* from the carotid plexus through the deep petrosal nerve; before entering the ganglion these two nerves join to form the nerve of the pterygoid canal.

FIG. 885.—The right sphenopalatine ganglion and its branches.



The *greater superficial petrosal nerve* is given off from the genicular ganglion of the facial nerve; it receives a branch from the tympanic plexus, passes through the hiatus of the facial canal, enters the cranial cavity, and runs forwards beneath the dura mater in a groove on the anterior surface of the petrous portion of the temporal bone. It then enters the cartilaginous substance which fills the foramen lacerum, and unites with the deep petrosal nerve to form the nerve of the pterygoid canal.

The *deep petrosal nerve* is given off from the carotid plexus, and runs through the carotid canal lateral to the internal carotid artery. It then enters the cartilaginous substance which fills the foramen lacerum, and joins with the greater superficial petrosal nerve to form the nerve of the pterygoid canal.

The *nerve of the pterygoid canal* (Vidian nerve), formed by the junction of the two preceding nerves in the cartilaginous substance which fills the foramen lacerum, is accompanied through the pterygoid canal by the corresponding artery, and is joined by a small ascending *sphenoidal branch* from the otic ganglion. Finally, it enters the pterygopalatine fossa, and joins the sphenopalatine ganglion.

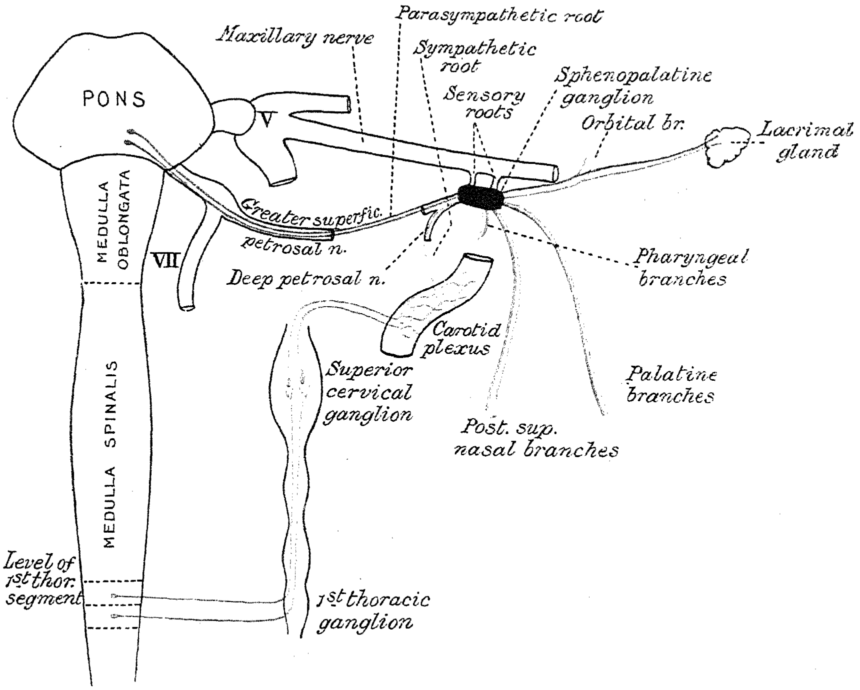
The *branches* of the sphenopalatine ganglion are divisible into four groups, viz. orbital, palatine, posterior superior nasal, and pharyngeal.

The *orbital branches* are two or three delicate filaments, which enter the orbit by the inferior orbital fissure, and are distributed to the periosteum, the Orbitalis muscle, and the lacrimal gland; twigs pass through the posterior ethmoidal foramen to the sphenoidal and ethmoidal air-sinuses.

The *palatine nerves* are distributed to the roof of the mouth, the soft palate, the tonsil, and the lining membrane of the nasal cavity. Most of their fibres are derived from the sphenopalatine branches of the maxillary nerve. They are three in number: anterior, middle, and posterior.

The *anterior palatine nerve* descends through the pterygopalatine canal, emerges upon the hard palate through the greater palatine foramen, and runs forwards in a groove on the inferior surface of the hard palate, nearly as far as the incisor teeth. It supplies the gums, and the mucous membrane and glands

FIG. 886.—A scheme showing the roots and the branches of distribution of the sphenopalatine ganglion.



of the hard palate, and communicates in front with the terminal filaments of the nasopalatine nerve. While in the pterygopalatine canal, it gives off *posterior inferior nasal branches*, which enter the nasal cavity through openings in the vertical part of the palatine bone, and ramify over the inferior nasal concha and middle and inferior meatuses; at its exit from the canal, palatine branches are distributed to both surfaces of the soft palate.

The *middle palatine nerve* descends through the pterygopalatine canal, emerges through one of the lesser palatine foramina and supplies branches to the uvula, tonsil, and soft palate.

The *posterior palatine nerve* descends through the pterygopalatine canal and emerges through one of the lesser palatine foramina; it supplies the uvula tonsil, and soft palate. The middle and posterior palatine nerves form, with the tonsillar branches of the glossopharyngeal nerve, a plexus around the tonsil.

The *posterior superior nasal branches* enter the posterior part of the nasal cavity through the sphenopalatine foramen, and supply the mucous membrane covering the superior and middle nasal conchæ, the lining of the posterior ethmoidal air-sinuses, and the posterior part of the nasal septum. One branch, longer and larger than the others, is named the *nasopalatine nerve*. It crosses

the roof of the nasal cavity below the orifice of the sphenoidal air-sinus, and then runs obliquely downwards and forwards between the periosteum and mucous membrane of the lower part of the septum. It descends to the roof of the mouth through the incisive canal, and communicates with the corresponding nerve of the opposite side and with the anterior palatine nerve. It furnishes a few filaments to the mucous membrane of the nasal septum.

The *pharyngeal nerve*, a small branch, arises from the posterior part of the ganglion, passes through the pharyngeal canal with the pharyngeal branch of the internal maxillary artery, and is distributed to the mucous membrane of the nasal part of the pharynx, behind the auditory tube.

The Mandibular Nerve (figs. 884, 887)

The **mandibular nerve** (inferior maxillary nerve) supplies the teeth and gums of the mandible, the skin of the temporal region, the auricula, the lower lip, the lower part of the face, and the muscles of mastication ; it also supplies the mucous membrane of the anterior two-thirds of the tongue. It is the largest division of the trigeminal nerve, and is made up of two roots : a large, sensory root proceeding from the inferior angle of the semilunar ganglion, and emerging almost immediately through the foramen ovale of the sphenoidal bone, and a small motor root (the motor part of the trigeminal) which passes beneath the ganglion, and unites with the sensory root, just outside the foramen ovale. Immediately beyond the junction of the two roots the nerve sends off from its medial side the nervus spinosus and the nerve to the Pterygoideus internus, and then divides into a small anterior and a large posterior trunk.

The **nervus spinosus** enters the skull through the foramen spinosum with the middle meningeal artery. It divides into two branches, anterior and posterior, which accompany the main divisions of the artery and supply the dura mater ; the posterior branch also supplies the mucous lining of the mastoid air-sinuses ; the anterior communicates with the meningeal branch of the maxillary nerve.

The **nerve to the Pterygoideus internus** is a slender branch which enters the deep surface of the muscle ; it gives one or two filaments to the otic ganglion.

The small anterior trunk gives off (*a*) a sensory branch named the buccinator nerve, and (*b*) motor branches, viz. the masseteric, deep temporal, and external pterygoid nerves ; these motor branches, together with the nerve to the Pterygoideus internus, are sometimes grouped under the name of the *nervus masticatorius.*

The **buccinator nerve** (long buccal nerve) passes forwards between the two heads of the Pterygoideus externus, and downwards beneath or through the lower part of the Temporalis ; it emerges from under the anterior border of the Masseter, and unites with the buccal branches of the facial nerve. It furnishes a branch to the Pterygoideus externus during its passage through that muscle, and may give off the anterior deep temporal nerve. The buccinator nerve supplies the skin over the anterior part of the Buccinator, and the mucous membrane lining its inner surface.

The **masseteric nerve** passes lateralwards, above the Pterygoideus externus, in front of the mandibular articulation, and behind the tendon of the Temporalis ; it crosses the posterior part of the mandibular notch with the masseteric artery, ramifies in the deep surface of the Masseter, and gives a filament to the mandibular joint.

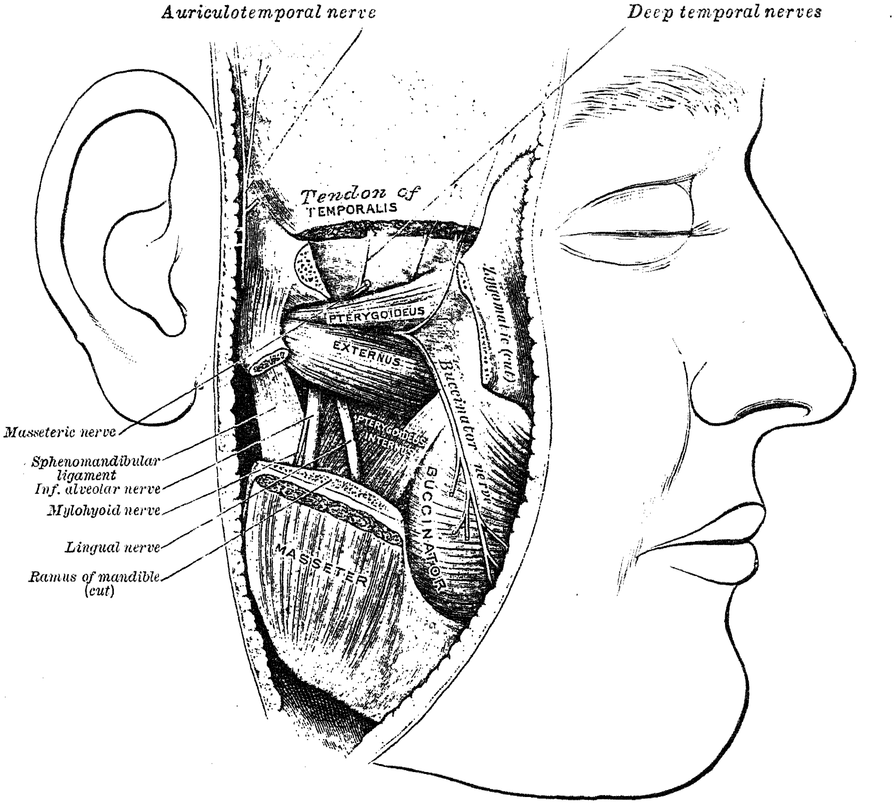
The **deep temporal nerves** are two in number, anterior and posterior. They pass above the upper border of the Pterygoideus externus and enter the deep surface of the Temporalis. The *posterior branch*, of small size, is placed at the posterior part of the temporal fossa, and sometimes arises in common with the masseteric nerve. The *anterior branch* is frequently given off from the buccinator nerve, and then ascends over the upper head of the Pterygoideus externus. A third or intermediate branch is often present.

The **nerve to the Pterygoideus externus** enters the deep surface of the muscle. It may arise separately from the anterior division of the mandibular nerve, or in conjunction with the buccinator nerve.

The large posterior trunk of the mandibular nerve is for the most part sensory, but receives a few filaments from the motor root. It divides into auriculotemporal, lingual, and inferior alveolar nerves.

The **auriculotemporal nerve** generally arises by two roots, which encircle the middle meningeal artery. It runs backwards beneath the Pterygoideus externus to the medial side of the neck of the mandible. It then turns upwards with the superficial temporal artery, between the auricula and condyle of the mandible, under cover of the parotid gland; escaping from beneath the gland, it ascends over the zygomatic arch, and divides into superficial temporal branches.

Fig. 887.—The right Pterygoideus externus and the branches of the mandibular nerve in relation to it.



The auriculotemporal nerve communicates with the facial nerve and the otic ganglion. The branches to the facial nerve, usually two in number, pass forwards behind the neck of the mandible and join the facial nerve at the posterior border of the Masseter. The filaments to the otic ganglion are derived from the roots of the auriculotemporal nerve close to their origin.

The *branches* of the auriculotemporal nerve are the anterior auricular, branches to the external acoustic meatus, articular, parotid, and superficial temporal.

The *anterior auricular branches* are usually two in number: they supply the front of the upper part of the auricula, being distributed principally to the skin covering the front of the helix and tragus.

The *branches to the external acoustic meatus*, two in number, supply the skin lining the meatus, which they enter between its bony and cartilaginous portions; the upper one sends a filament to the tympanic membrane.

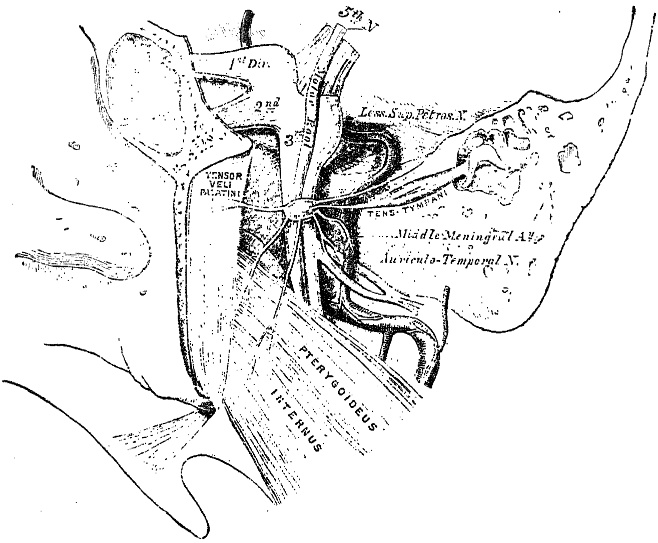
The *articular branches* consist of one or two twigs which enter the posterior part of the mandibular joint.

The *parotid branches* supply the parotid gland.

The *superficial temporal branches* accompany the superficial temporal artery and its terminal branches; they supply the skin of the temporal region and communicate with the facial and zygomaticotemporal nerves.

The **lingual nerve** lies at first beneath the Pterygoideus externus, medial to and in front of the inferior alveolar nerve, to which it is often joined by a branch which may cross the internal maxillary artery. The chorda tympani branch of the facial nerve also joins it at an acute angle in this situation. The nerve then runs between the Pterygoideus internus and the ramus of the mandible, and passes obliquely to the side of the tongue over the Constrictor pharyngis superior and Styloglossus, and then between the Hyoglossus and deep part of the submaxillary gland; it finally runs across the duct of the submaxillary gland, and along the tongue to its tip, lying immediately beneath the mucous membrane.

Fig. 888.—The right otic ganglion and its branches.



In addition to receiving the chorda tympani and the branch from the inferior alveolar nerve, already referred to, the lingual nerve sends two or three branches to the submaxillary ganglion, and, at the anterior margin of the Hyoglossus muscle, forms two or three loops of communication with twigs of the hypoglossal nerve.

The *branches* of the lingual nerve supply the sublingual gland, the mucous membrane of the mouth, the gums, and the mucous membrane of the anterior two-thirds of the tongue; the terminal filaments join, at the tip of the tongue, with those of the hypoglossal nerve.

The **inferior alveolar nerve** (inferior dental nerve) is the largest branch of the mandibular nerve. It descends with the inferior alveolar artery, at first beneath the Pterygoideus externus, and then between the sphenomandibular ligament and the ramus of the mandible to the mandibular foramen. Here it enters the mandibular canal, and runs below the teeth as far as the mental foramen, where it divides into an incisive and a mental branch.

The branches of the inferior alveolar nerve are the mylohyoid, dental, incisive, and mental.

The *mylohyoid nerve* is derived from the inferior alveolar nerve just before the latter enters the mandibular foramen. It descends in a groove on the medial surface of the ramus of the mandible, and reaching the under surface of the Mylohyoideus supplies this muscle and the anterior belly of the Digastricus.

of the fibres, instead of following the long pathway, are relayed to the thalamus by shorter neurons. From the thalamus new fibres arise and convey the impulses to the cerebral cortex behind the central sulcus.

It will be observed that in most cases there are three cell-stations interposed in the course of the sensory impulses; for clinical purposes, therefore, three groups of neurons are recognised: (1) the *lowest sensory neurons* which comprise the cells of the posterior root ganglia, and their peripheral and central processes; (2) the *intermediate sensory neurons* between these and the thalamus; and (3) the highest sensory neurons which are the cells of the thalamus and the fibres passing from them to the cerebral cortex.

The Cerebellar Systems.

The cerebellum acts as a great coordinating centre for the muscles of the body generally, so that impulses reach it from all the sensory centres of the rest of the brain and of the medulla spinalis, while impulses are conveyed from it to other coordinating and motor nuclei in the cerebrospinal axis. Only the larger tracts can be summarised here.

Afferent tracts.—A considerable number of afferent impulses reach the cerebellum by way of the medulla spinalis through the fibres of the posterior nerve roots. In the medulla spinalis there are three main pathways. The entering fibres may end around the cells of the dorsal nucleus; the fibres from these cells form the direct cerebellar tract (posterior spino-cerebellar fasciculus) of the same side, and are carried up to the medulla oblongata where they enter the restiform body and are conveyed to the cortex of the vermis of the cerebellum. A second group of entering fibres arborise around the cells of the posterior grey column of the medulla spinalis; of the fibres of these cells some cross to the opposite side while others pass up the same side, in each instance forming an anterior spinocerebellar tract which traverses the medulla spinalis in the superficial antero-lateral tract, runs through the medulla oblongata and pons, and then turns in to reach the cerebellar cortex by way of the brachium conjunctivum. The third group of entering fibres runs up in the fasciculus gracilis and fasciculus cuneatus, and ends in the nucleus gracilis and nucleus cuneatus; the fibres arising from the cells of these nuclei pass in the restiform body to reach the cerebellar cortex.

Two important afferent tracts to the cerebellum run from the brain-stem, viz. the vestibulocerebellar and the tectocerebellar. The vestibulocerebellar tract arises from the vestibular nuclei in the floor of the fourth ventricle, and runs up in the restiform body to the cerebellar cortex. The tectocerebellar tract has its origin in the cells of the superior and inferior colliculi and enters the cerebellum through the brachium conjunctivum.

Of the remaining afferent fibres to the cerebellum the most important group is that of the cerebro-ponto-cerebellar tracts. These fibres arise from cells of the cerebral cortex, travel downwards through the internal capsule and cerebral peduncle, and end by arborising round the cells of the nuclei pontis. New fibres arise from the cells of these nuclei, cross the middle line, pass through the brachium pontis, and end in the cerebellar cortex.

Efferent tracts.—The efferent tracts from the cerebellum originate from cells of the cortex and run to arborise around cells of the cerebellar nuclei; no fibres pass directly from the cerebellar cortex to the rest of the brain or to the medulla spinalis. Several small groups of fibres arising from the cerebellar nuclei run to various nuclei in the cerebrospinal axis, but the chief efferent tract is that which forms the greater part of the brachium conjunctivum, crosses the middle line, and runs mainly to the red nucleus, giving some fibres to the thalamus. From the red nucleus the rubrospinal tract arises, crosses to the opposite side, and travels down in the pons and medulla oblongata to the lateral funiculus of the spinal medulla, where it ultimately ends around the motor cells in the anterior grey column.

Two other efferent tracts may be mentioned; fibres from the cerebellar nuclei run to the vestibular nuclei and to the inferior olivary nuclei; from these in turn are derived the vestibulospinal and olivospinal tracts of the opposite side of the medulla spinalis.

Applied Anatomy.—The chief symptoms of diseases of the brain and medulla spinalis depend upon the particular systems of neurons picked out for attack, and some of them may be briefly summarised as follows. *Motor paralysis* of the *spastic* type, with rigidity of the muscles and increased reflexes, follows destruction of the upper motor neurons; *flaccid* paralysis, with loss of the reflexes and rapid muscular atrophy, follows destruction of the lower motor neurons. *Sensory paralysis* follows injury to any part of the sensory path; in tabes it is due to injury of the lowest sensory neurons, in hemiplegia to destruction of the highest sensory axon as it traverses the occipital part of the internal capsule. *Dissociation of sensations*, or the loss of some forms of sensation while others remain unimpaired, is seen in a number of conditions such as tabes and syringomyelia; it shows that the paths through which various forms of sensation travel to the brain are different. *Abnormalities of reflex actions* are of very great help in the diagnosis of nervous complaints. The numerous *superficial or skin reflexes* (e.g. the scapular, irritation of the skin over the scapula produces contraction of the scapular muscles; the abdominal, stroking the abdomen causes its retraction; the cremasteric, stroking the inner side of the thigh causes retraction of the testis on that side; the plantar, tickling the sole of the

Fig. 889.—A scheme showing the roots and the branches of distribution of the otic ganglion.

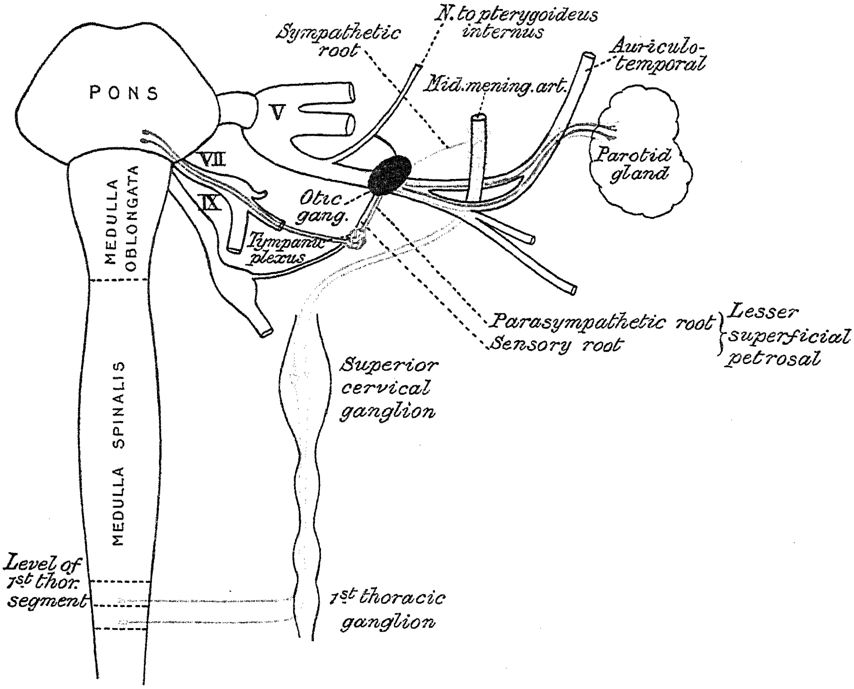
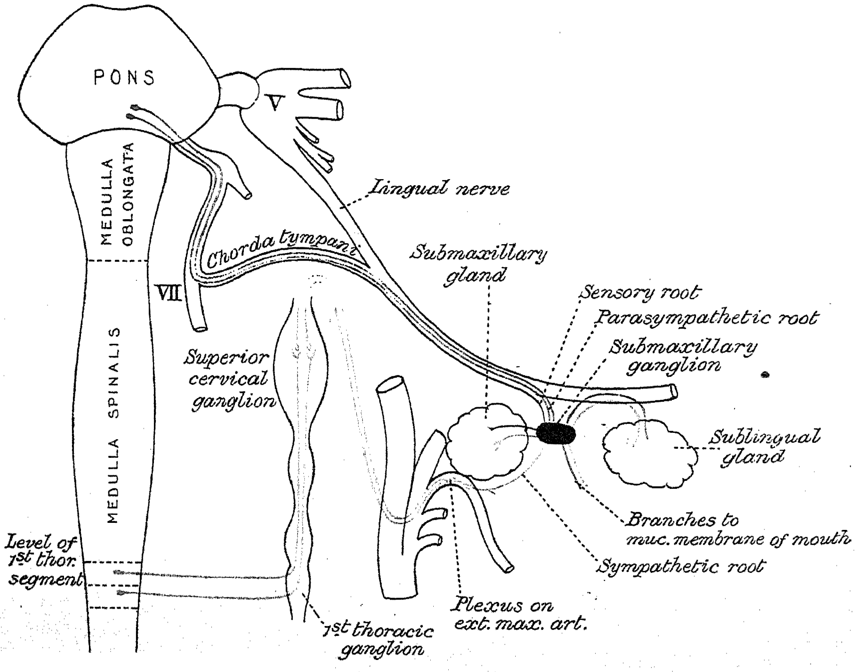


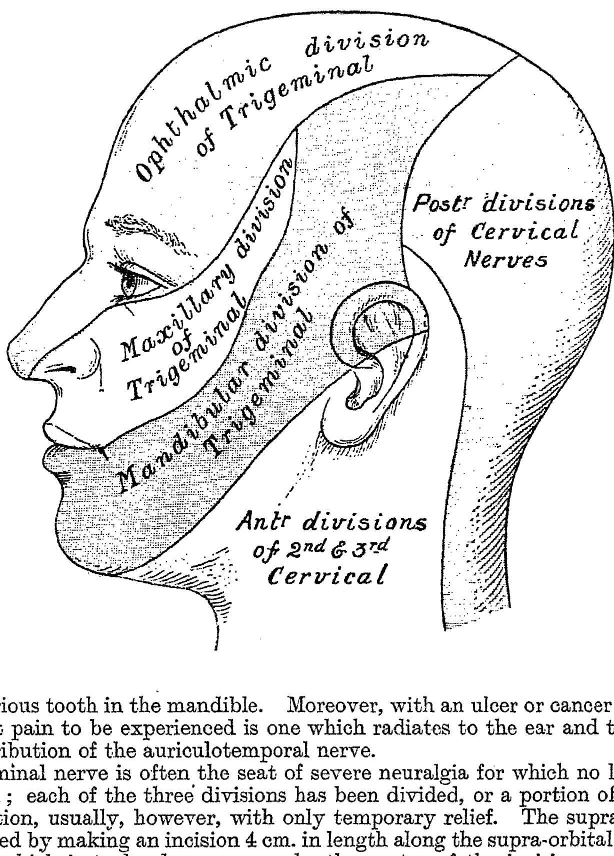
Fig. 890.—A scheme showing the roots and the branches of distribution of the submaxillary ganglion.



in severe cases pain may radiate over the branches of the other main divisions. The commonest example of this condition is the neuralgia which is so often associated with dental caries—here, although the tooth itself may not appear to be painful, the most distressing referred pains may be experienced, and these are at once relieved by treatment directed to the affected tooth.

Many other examples of trigeminal reflexes could be quoted, but it will be sufficient to mention the more common ones. In the area of the ophthalmic nerve, severe supra-orbital pain is commonly associated with acute glaucoma or with disease of the frontal or ethmoidal air-sinuses. Malignant growths or empyema of the maxillary antrum, or unhealthy conditions about the inferior conchæ or the septum of the nose, are often found giving rise to 'second division' neuralgia, and should be always looked for in the absence of dental disease in the maxilla. It is on the mandibular nerve, however, that some of the most striking reflexes are seen. It is quite common to meet with patients who complain of pain in the ear, in whom there is no sign of aural disease and the cause is usually to be

FIG. 891.—A diagram showing the cutaneous nerve-areas of the face and scalp.



found in a carious tooth in the mandible. Moreover, with an ulcer or cancer of the tongue, often the first pain to be experienced is one which radiates to the ear and temporal fossa, over the distribution of the auriculotemporal nerve.

The trigeminal nerve is often the seat of severe neuralgia for which no local cause can be discovered; each of the three divisions has been divided, or a portion of nerve excised for this affection, usually, however, with only temporary relief. The supra-orbital nerve may be exposed by making an incision 4 cm. in length along the supra-orbital margin, below the eyebrow which is to be drawn upwards, the centre of the incision corresponding to the supra-orbital notch. The skin and Orbicularis oculi having been divided, the nerve can be easily found emerging from the notch, and lying in some loose cellular tissue.

The infra-orbital nerve has been divided at its exit by an incision on the cheek; or the infra-orbital canal can be injected with absolute alcohol; or the whole nerve, together with the sphenopalatine ganglion as far back as the foramen rotundum, may be removed, but even then a return of the neuralgia in some other branches of the trigeminal nerve is the rule. Intracranial resection of the maxillary nerve between the semilunar ganglion and the foramen rotundum is an anatomical possibility.

The inferior alveolar nerve can be reached by a transverse incision over the ramus of the mandible placed so as to avoid injury to the facial nerve; the Masseter having been divided, a small trephine is applied to the ramus immediately beneath the mandibular notch, and, when the bone has been removed, the nerve is found lying on the Pterygoideus internus just as it enters the mandibular foramen, and it can here be resected.

The lingual nerve is occasionally divided with the view of relieving the pain in cancerous disease of the tongue. This may be done in that part of its course where it lies below and

behind the last molar tooth. If a line be drawn from the middle of the crown of the last molar tooth to the angle of the mandible it will cross the nerve, which lies about 1·25 cm. behind the tooth, parallel to the bulging alveolar ridge on the inner side of the body of the bone. The tongue should be pulled forwards and over to the opposite side, when the nerve can be seen standing out as a firm cord under the mucous membrane by the side of the tongue, and after division of the mucous membrane can be easily seized with a hook and a portion excised. This is a simple enough operation on the cadaver, but when the disease is extensive and has extended to the floor of the mouth, as is generally the case when the division is required, the operation is not practicable.

In severe cases of neuralgia of the trigeminal nerve, the trunks of the maxillary and mandibular nerves may be injected with alcohol; if this treatment fails the semilunar ganglion may be removed in whole or in part. Rose was the first to perform this operation; and he reached the ganglion by trephining the base of the skull in the position of the foramen ovale, after dividing the zygomatic arch, in front and behind, and turning it and the Masseter downwards, and cutting through the coronoid process of the mandible, and turning it and the Temporalis upwards. A more efficient method appears to be that known as the Krause-Hartley method. The bone forming the temporal fossa having been removed to a sufficient extent, the dura mater beneath the temporal lobe of the brain is gradually raised from the middle fossa, until the foramen spinosum, with the middle meningeal artery passing through it, is exposed. This vessel is to be ligatured in two places, and divided between the ligatures; and then by further raising the dura mater, the foramina ovale and rotundum will be exposed, with the mandibular and maxillary nerves passing through them. These nerves are to be clearly defined and divided. The dura mater is then to be raised from the ganglion, when the ophthalmic nerve will be exposed and can be divided, and the ganglion, by means of a little careful dissection, raised from its bed and removed. In some cases where the neuralgia has been limited to the maxillary nerve an intracranial resection of that nerve alone has been performed with great success. In other cases where the disease has not affected the ophthalmic division, resection of the lateral half of the ganglion only, with the maxillary and mandibular nerves, has been performed, thus leaving the sensory nerve supply to the cornea intact. The motor root is usually resected with the mandibular nerve, leading to complete paralysis of the muscles of mastication on that side.

The Abducent Nerve (fig. 882)

The **abducent nerve** supplies the Rectus lateralis oculi.

Its fibres arise from a small nucleus which is situated in the upper part of the rhomboid fossa, close to the middle line and beneath the colliculus facialis. They pass downwards and forwards through the pons, and emerge in the furrow between the lower border of the pons and the upper end of the pyramid of the medulla oblongata.

From the nucleus of the abducent nerve, fibres pass through the medial longitudinal fasciculus to the oculomotor nerve of the opposite side, along which they are carried to the Rectus medialis. The Rectus lateralis of one eye and the Rectus medialis of the other may therefore be said to receive their nerves from the same nucleus (fig. 892).

The abducent nerve runs forwards and lateralwards in the cisterna pontis, in contact with the under surface of the pons, and usually dorsal to the anterior inferior cerebellar artery. It pierces the dura mater on the lateral part of the dorsum sellæ of the sphenoidal bone, and lies in a notch on the edge of this part of the bone. It next traverses the cavernous sinus, lying to the lateral side of the internal carotid artery, and runs into the orbital cavity through the medial end of the superior orbital fissure. It passes within the annulus tendineus from which the Recti muscles of the eyeball arise, beneath the oculomotor and nasociliary nerves, and finally enters the ocular surface of the Rectus lateralis.

In the cavernous sinus the abducent nerve is joined by several filaments from the carotid and cavernous plexuses, and by one from the ophthalmic nerve.

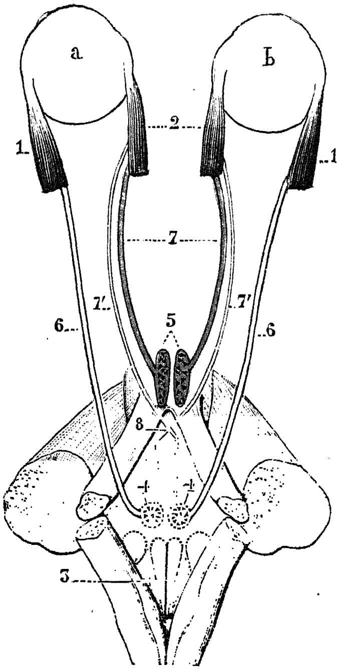
The oculomotor, trochlear, ophthalmic, and abducent nerves bear certain relations to each other in the cavernous sinus, at the superior orbital fissure, and in the cavity of the orbit, as follows.

In the *cavernous sinus* (fig. 893), the oculomotor, trochlear, and ophthalmic nerves are placed in the lateral wall of the sinus, in the order given, from above downwards; the abducent nerve lies at the lateral side of the internal carotid artery. As these nerves pass forwards to the superior orbital fissure,

the oculomotor and ophthalmic nerves divide into branches, and the abducent nerve approaches the others; so that their relative positions are considerably changed.

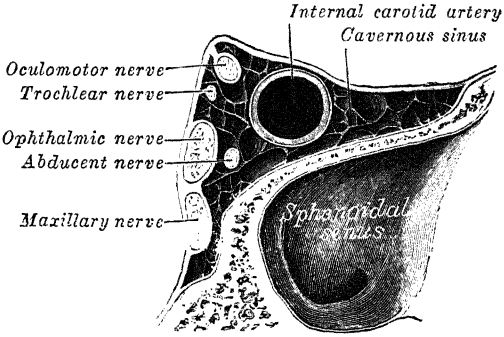
In the *superior orbital fissure* (fig. 894), the trochlear nerve and the frontal and lacrimal divisions of the ophthalmic nerve lie in this order from the medial to the lateral side upon the same plane; they enter the cavity of the orbit above the muscles. The remaining nerves enter the orbit within the annulus tendineus from which the Recti muscles of the eyeball take origin. The superior division of the oculomotor nerve is the highest of these; beneath this lies the nasociliary branch of the ophthalmic nerve; then the inferior division of the oculomotor nerve; and the abducent nerve lowest of all.

FIG. 892.—A diagram showing the mode of innervation of the Rectus medialis et Rectus lateralis of the eye (after Duval and Laborde). (Testut.)



a. Left eyeball. *b.* Right eyeball. 1. Rectus lateralis. 2. Rectus medialis. 3. Rhomboid fossa. 4. Nucleus of abducent nerve. 5. Nucleus of oculomotor nerve. 6. Abducent nerve. 7. Nerve to Rectus medialis arising from the nucleus of the oculomotor of the same side. 7'. Nerve to Rectus medialis arising from the nucleus of the abducent of the opposite side. 8. Decussation of the fibres of the abducent nerve to the Rectus medialis.

FIG. 893.—An oblique section through the left cavernous sinus. Posterior aspect.



In the *orbit* (fig. 881) the trochlear, frontal, and lacrimal nerves lie immediately beneath the periosteum, the trochlear nerve resting on the Obliquus superior, the frontal on the Levator palpebræ superioris, and the lacrimal on the Rectus lateralis. The superior division of the oculomotor nerve lies immediately beneath the Rectus superior, while the nasociliary nerve crosses the optic nerve to reach the medial wall of the orbit. Beneath these is the optic nerve, surrounded anteriorly by the ciliary nerves, and having the ciliary ganglion on its lateral side between it and the Rectus lateralis. Below the optic nerve are the inferior division of the oculomotor nerve, and the abducent nerve, the latter lying on the medial surface of the Rectus lateralis.

Applied Anatomy.—The abducent nerve is frequently involved in fractures of the base of the skull. The result of paralysis of this nerve is medial or convergent squint. Diplopia is also present. When injured so that its function is destroyed, there is, in addition to the paralysis of the Rectus lateralis oculi, often a certain amount of contraction of the pupil, because some of the sympathetic fibres to the Dilatator pupillæ muscle are conveyed through this nerve.

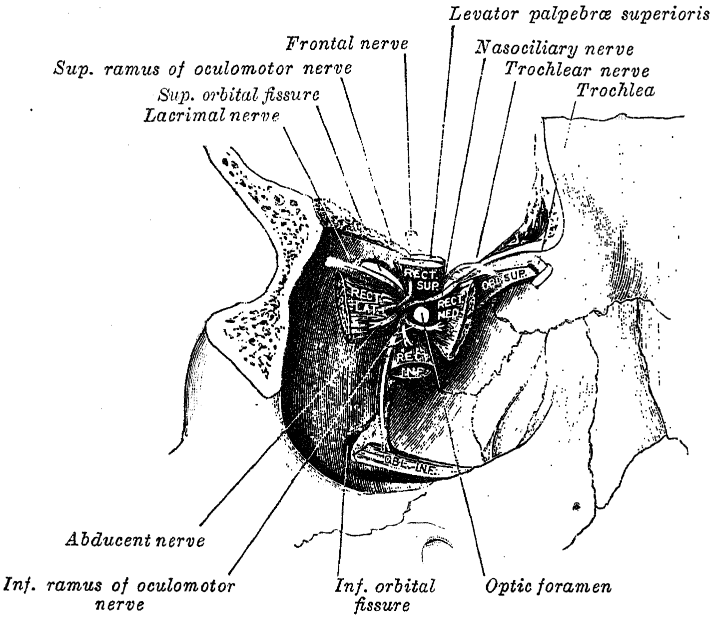
THE FACIAL NERVE (figs. 895, 897)

The **facial nerve** consists of a motor and a sensory part, the latter being frequently described under the name of the *nervus intermedius of Wrisberg* (fig. 798). The two parts appear at the lower border of the pons in the recess

between the olive and the restiform body, the motor part being the more medial; immediately to the lateral side of the sensory part is the acoustic nerve.

The motor part supplies the muscles of the face, scalp, and auricula, the Buccinator, Platysma, Stapedius, Stylohyoideus, and posterior belly of the Digastricus; it also contains some fibres which constitute the vasodilator and secretory nerves of the submaxillary and sublingual glands, and are conveyed to these glands through the chorda tympani nerve. The sensory part conveys from the chorda tympani nerve the fibres of taste for the anterior two-thirds of the tongue.

Fig. 894.—A dissection showing the origins of the right ocular muscles, and the nerves entering the orbit through the superior orbital fissure.



The *motor* root arises from a nucleus which lies deeply in the reticular formation of the lower part of the pons. This nucleus is situated above the nucleus ambiguus, behind the superior olivary nucleus, and medial to the spinal tract of the trigeminal nerve. From this origin the fibres pursue a curved course in the substance of the pons. They first pass backwards and medialwards, and, reaching the posterior end of the nucleus of the abducent nerve, run upwards close to the middle line beneath the colliculus facialis. At the anterior end of the nucleus of the abducent nerve they make a second bend, and run downwards and forwards through the pons to their point of emergence between the olive and the restiform body (figs. 798, 809).

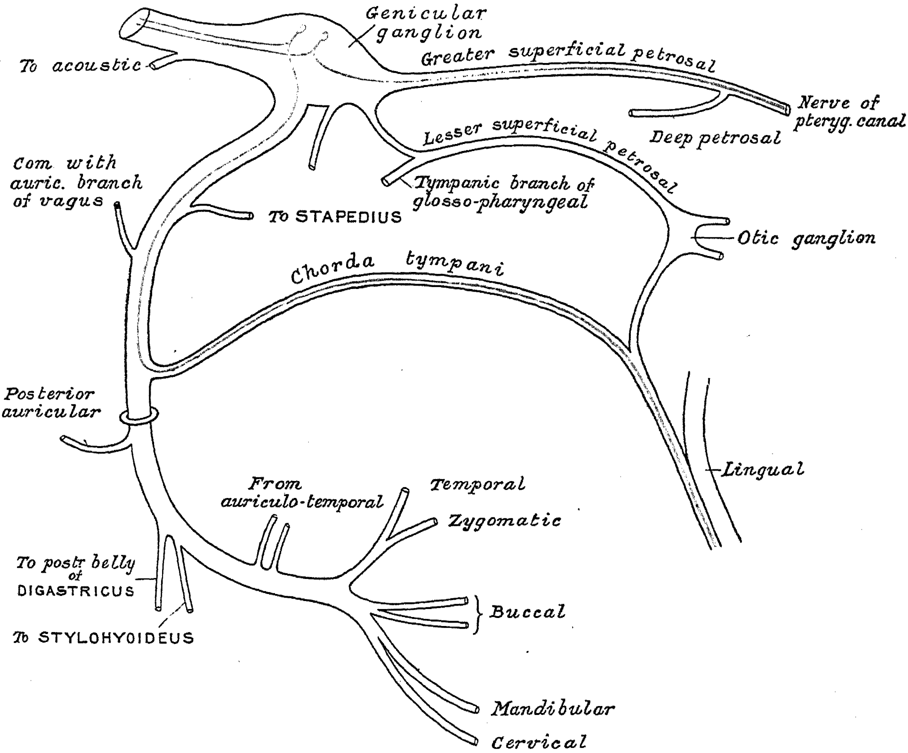
Some fibres from the nucleus of the oculomotor nerve are said to descend in the medial longitudinal fasciculus and join the motor root of the facial nerve before it leaves the pons. These fibres are said to supply the Orbicularis oculi, Corrugator, and Frontalis, since these muscles have been observed to escape paralysis in lesions of the motor nucleus of the facial nerve.*

The *sensory* root arises from the genicular ganglion, which is situated on the geniculum of the facial nerve in the facial canal of the temporal bone. The cells of this ganglion are unipolar, and their single processes divide in a T-shaped manner into central and peripheral branches. The central branches leave the trunk of the facial nerve in the internal acoustic meatus, and form the sensory root of the nerve; the peripheral branches are continued into the chorda tympani and greater superficial petrosal nerves. Entering the brain at the lower border

* See footnote, p. 828.

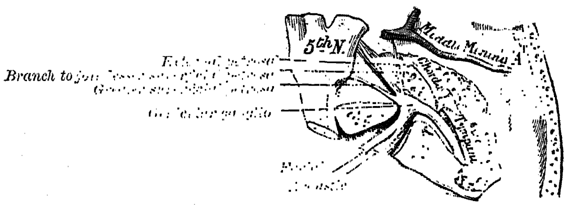
of the pons, between the motor root and the acoustic nerve, the fibres of the sensory root of the facial nerve pass into the substance of the medulla oblongata and end in the upper part of the terminal nucleus of the glossopharyngeal nerve and in the nerve-cells of the fasciculus solitarius (nucleus tractus solitarii).

FIG. 895.—A plan of the facial nerve. The course of the sensory fibres is represented by the blue lines.



From their attachments to the brain, the two roots of the facial nerve pass lateralwards and forwards with the acoustic nerve to the opening of the internal acoustic meatus. In the meatus the motor root lies in a groove on the upper and anterior surface of the acoustic nerve, the sensory root being placed between them.

FIG. 896.—The course and connexions of the facial nerve in the temporal bone.



At the bottom of the meatus, the facial nerve enters the facial canal, which it traverses to its termination at the stylomastoid foramen. In this canal the nerve runs at first lateralwards over the vestibule, and reaching the medial wall of the epitympanic recess, bends suddenly backwards and arches downwards behind the tympanic cavity to the stylomastoid foramen. The point where it bends suddenly backwards is named the *geniculum*; it presents a reddish

gangliform swelling, the *genicular ganglion*, or nucleus of the sensory root of the nerve (fig. 896). On emerging from the stylomastoid foramen, the facial nerve runs forwards in the substance of the parotid gland, crosses the styloid process and the external carotid artery, and divides behind the ramus of the mandible into branches which form a network (*parotid plexus*) and are distributed to the superficial muscles on the side of the head, face, and upper part of the neck.

The *branches of communication* of the facial nerve may be arranged as follows:

In the internal acoustic meatus	With the acoustic nerve.
At the genicular ganglion .	With sphenopalatine ganglion by the greater superficial petrosal nerve. With the otic ganglion by a branch which joins the lesser superficial petrosal nerve. With the sympathetic plexus on the middle meningeal artery.
In the facial canal . .	With the auricular branch of the vagus nerve.
At its exit from the stylomastoid foramen . .	With the glossopharyngeal, vagus, great auricular, and auriculotemporal nerves.
Behind the ear . . .	With the lesser occipital nerve.
On the face	With the trigeminal nerve.
In the neck	With the cutaneous cervical nerve.

In the internal acoustic meatus some minute filaments pass from the facial nerve to the acoustic nerve.

The *greater superficial petrosal nerve* arises from the genicular ganglion of the facial nerve, and consists chiefly of sensory branches which are distributed to the mucous membrane of the soft palate; but it probably contains a few fibres which form the parasympathetic root of the sphenopalatine ganglion. It receives a twig from the tympanic plexus, passes forwards through the hiatus of the facial canal, and runs in a sulcus on the anterior surface of the petrous portion of the temporal bone beneath the semilunar ganglion, to the foramen lacerum. In this foramen it is joined by the deep petrosal nerve from the sympathetic plexus on the internal carotid artery, to form the nerve of the pterygoid canal which passes forwards through the pterygoid canal and ends in the sphenopalatine ganglion. From the genicular ganglion of the facial nerve a branch runs to join the small superficial petrosal nerve, and is conveyed through this nerve to the otic ganglion. The sympathetic plexus on the middle meningeal artery is joined to the genicular ganglion by the *external petrosal nerve.* According to Arnold, a twig passes back from the genicular ganglion to the acoustic nerve.

Before the facial nerve emerges from the stylomastoid foramen, it receives a twig from the auricular branch of the vagus.

After its exit from the stylomastoid foramen, the facial nerve receives a twig from the glossopharyngeal nerve, and communicates with the great auricular and auriculotemporal nerves in the parotid gland, with the lesser occipital nerve behind the ear, with the terminal branches of the trigeminal nerve on the face, and with the cutaneous cervical nerve in the neck.

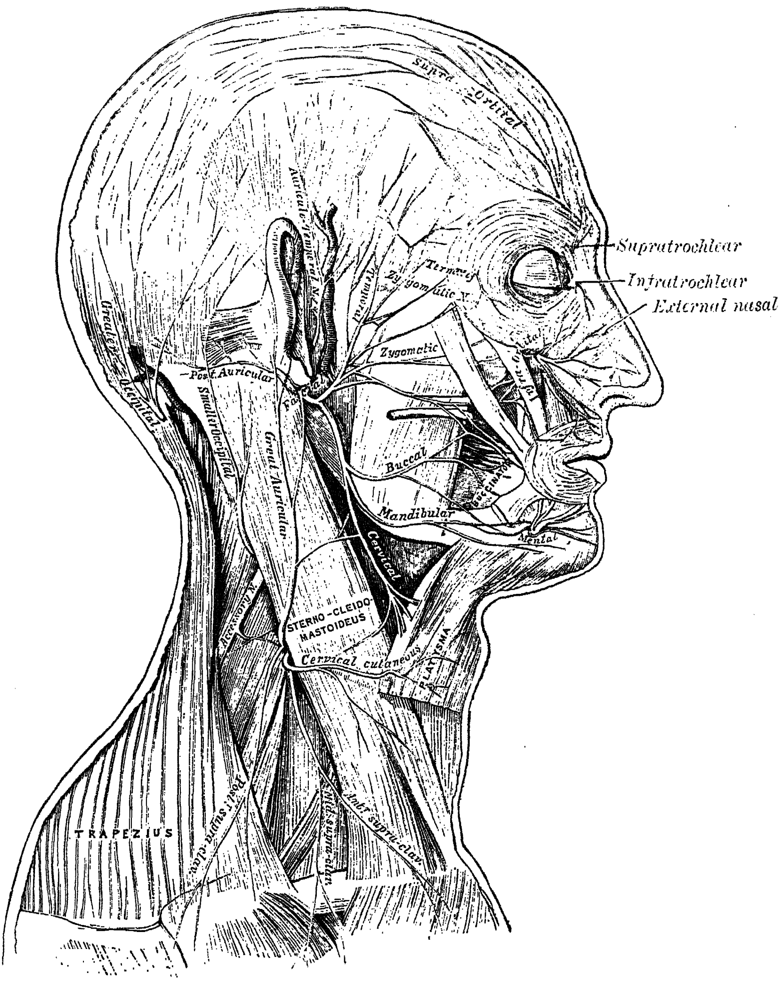
The *branches of distribution* (figs. 895, 897) of the facial nerve may be grouped as follows:

Within the facial canal .	Nerve to the Stapedius muscle. Chorda tympani.
At its exit from the stylomastoid foramen .	Posterior auricular. Digastric. Stylohyoid.
On the face	Temporal. Zygomatic. Buccal. Mandibular. Cervical.

The **nerve to the Stapedius** arises from the facial nerve opposite the pyramidal eminence on the posterior wall of the tympanic cavity; it passes forwards through a small canal to reach the muscle.

The **chorda tympani nerve** is given off from the facial nerve about 6 mm. above the stylomastoid foramen. It runs upwards and forwards in a canal, and enters the tympanic cavity through an aperture (*iter chordæ posterius*) on its posterior wall, close to the posterior border of the medial surface of the tympanic membrane and on a level with the upper end of the manubrium of the malleus. It traverses the tympanic cavity, between the fibrous and mucous layers of the tympanic membrane, crosses the manubrium of the malleus, and leaves the cavity through a channel situated at the inner end of the petrotympanic fissure,

Fig. 897.—The nerves of the right side of the scalp, face, and neck.



and named the *iter chordæ anterius or canal of Huguier*. The nerve now runs downwards and forwards between the Pterygoidei externus et internus on the medial surface of the spina angularis of the sphenoid (which it sometimes grooves) and on the medial surface of the Pterygoideus externus, where it joins, at an acute angle, the posterior border of the lingual nerve. It contains a few efferent fibres which enter the submaxillary ganglion, and through the latter are distributed to the submaxillary and sublingual glands; the majority of its fibres are afferent, and are continued onwards through the muscular substance of the tongue to the mucous membrane covering its anterior two-thirds; they constitute the nerve of taste for this portion of the tongue. Before uniting with the lingual nerve the chorda tympani is joined by a small branch from the otic ganglion.

The **posterior auricular nerve** arises close to the stylomastoid foramen and runs upwards in front of the mastoid process; here it is joined by a filament

from the auricular branch of the vagus nerve, and communicates with the posterior branch of the great auricular nerve, and with the lesser occipital nerve. As it ascends between the external acoustic meatus and mastoid process it divides into an auricular and an occipital branch. The *auricular branch* supplies the Auricularis posterior and the intrinsic muscles on the cranial surface of the auricula (pinna). The *occipital branch*, the larger, passes backwards along the superior nuchal line of the occipital bone, and supplies the Occipitalis.

The **digastric branch** arises close to the stylomastoid foramen, and divides into several filaments which supply the posterior belly of the Digastricus; one of these filaments joins the glossopharyngeal nerve.

The **stylohyoid branch** frequently arises in conjunction with the digastric branch; it is long and slender, and enters the Stylohyoideus about its middle.

The **temporal branches** cross the zygomatic arch to the temporal region. They supply the Auricularis anterior and Auricularis superior, and join with the zygomaticotemporal branch of the maxillary nerve, and with the auriculotemporal branch of the mandibular nerve. The more anterior branches supply the Frontalis, the Orbicularis oculi, and the Corrugator, and join the supra-orbital and lacrimal branches of the ophthalmic nerve.

The **zygomatic branches** run across the zygomatic bone to the lateral angle of the orbit; they supply the Orbicularis oculi, and join with filaments of the lacrimal nerve and the zygomaticofacial branch of the maxillary nerve.

The **buccal branches** pass horizontally forwards to be distributed below the orbit and around the mouth. The *superficial branches* run between the skin and the superficial muscles of the face, and supply the latter; some are distributed to the Procerus, joining at the medial angle of the orbit with the infratrochlear and external nasal nerves. The *deep branches* pass beneath the Zygomaticus and the Quadratus labii superioris, supplying them and forming an *infra-orbital plexus* with the superior labial branches of the infra-orbital nerve; these branches also supply the small muscles of the nose. The lower deep branches supply the Buccinator and Orbicularis oris, and join with filaments of the buccinator branch of the mandibular nerve.

The **mandibular branch** (ramus marginalis mandibulæ) passes forwards beneath the Platysma and Triangularis, near the lower border of the body of the mandible; it supplies the muscles of the lower lip and chin, and joins the mental branch of the inferior alveolar nerve.

The **cervical branch** (ramus colli) issues from the lower part of the parotid gland, runs forwards below the angle of the mandible and under cover of the Platysma to the front of the neck. It supplies the Platysma and communicates with the cutaneous cervical nerve.

Applied Anatomy.—Facial palsy is commonly unilateral, and may be either: (1) *peripheral*, from lesion of the facial nerve; (2) *nuclear*, from destruction of the facial nucleus; or (3) *central*, *cerebral*, or *supranuclear*, from injury in the brain to the fibres passing from the cortex through the internal capsule to the facial nucleus, or from injury to the face-area of the motor cortex itself. In supranuclear facial paralysis, which is usually part of a hemiplegia, it is the lower part of the face that is chiefly affected, while the forehead can be freely wrinkled on the palsied side, the eye can be closed fairly well, and the eyeball is not rolled up under the upper lid; emotional movements of the face are much better executed than voluntary; and the electrical reactions of the muscles on the affected side are not altered. If the paralysis is due to lesion of the facial nucleus, the Orbicularis oris escapes, as the nuclear origin of the nerve to this muscle seems to be connected with that of the tongue-nerves; otherwise the symptoms are identical with those of the common peripheral facial palsy, of which several types may be distinguished according to the point in its course at which the facial nerve is injured. If the lesion occurs (*a*) in the pons, facial paralysis is produced as in (*d*) below; taste and hearing are not affected, but the abducent nerve also will be paralysed because the fibres of the facial nerve loop round its nucleus in the pons. When the nerve is paralysed (*b*) in the petrous bone, in addition to the paralysis of the muscles of expression, there is loss of taste in the anterior part of the tongue, and the patient is unable, from involvement of the chorda tympani, to recognise the difference between bitters and sweets, acids and salines. The mouth is dry, because the salivary glands are not secreting; and the sense of hearing is affected from paralysis of the Stapedius. When the cause of the paralysis is (*c*) fracture of the base of the skull, the acoustic and petrosal nerves are usually involved. But by far the commonest cause of facial palsy is (*d*) exposure of the nerve to cold or injury at or after its exit from the stylomastoid foramen (Bell's paralysis). In these cases the face looks asymmetrical even when at rest, and more so in the old than in the young. The

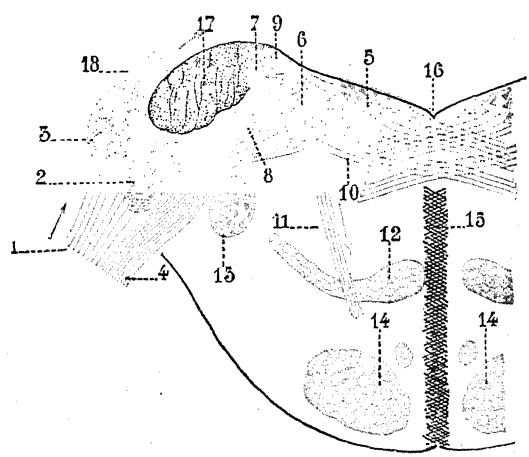
affected side of the face and forehead remains motionless when voluntary or emotional movement is attempted. The lines on the forehead are smoothed out, the eye can be shut only by hand, tears fail to enter the lacrimal puncta because they are no longer in contact with the conjunctiva, the conjunctival reflex is absent, and efforts to close the eye merely cause the eyeball to roll upwards until the cornea lies under the upper lid. The tip of the nose is drawn over towards the sound side; the nasolabial fold is partially obliterated on the affected side, and the ala nasi does not move properly on respiration. The lips remain in contact on the paralysed side, and cannot be put together for whistling; when a smile is attempted the angle of the mouth is drawn up on the unaffected side; on the affected side the lips remain nearly closed, and the mouth assumes a characteristic triangular form. During mastication food accumulates in the cheek, from paralysis of the Buccinator, and dribbles or is pushed out from between the paralysed lips. On protrusion the tongue seems to be thrust over towards the palsied side, but verification of its position by reference to the incisor teeth will show that this is not really so. The Platysma and the muscles of the auricula are paralysed; in severe cases the articulation of labials is impaired. The electrical reactions of the affected muscles are altered (reaction of degeneration), and the degree to which this alteration has taken place after a week or ten days gives a valuable guide to the prognosis. Most cases of Bell's palsy recover completely.

The facial nerve is at fault in cases of so-called 'histrionic spasm,' which consists in an almost constant and uncontrollable twitching of some or all of the muscles of the face. This twitching is sometimes so severe as to cause great discomfort and annoyance to the patient, and to interfere with sleep, and for its relief the facial nerve has been stretched. The operation is performed by making an incision behind the ear, from the root of the mastoid process to the angle of the mandible. The parotid is turned forwards and the dissection carried along the anterior border of the Sternocleidomastoideus and mastoid process, until the upper border of the posterior belly of the Digastricus is found. The nerve is parallel to this on about the level of the middle of the mastoid process. When found, the nerve must be stretched by passing a blunt hook beneath it and pulling it forwards and outwards. Too great force must not be used, for fear of permanent injury to the nerve.

The Acoustic Nerve

The **acoustic nerve** appears in the groove between the pons and medulla oblongata behind the facial nerve and in front of the restiform body; it is distributed to the internal ear. It consists of two sets of fibres, which, although differing in their central connexions, are both concerned in the transmission of afferent impulses from the internal ear to the medulla oblongata and pons, and from there, by means of fibres which arise from collections of grey substance in these structures, to the cerebrum and cerebellum. One set of fibres forms the vestibular nerve, and arises from the cells of the vestibular ganglion situated in the bottom of the internal acoustic meatus; the other set constitutes the cochlear nerve, and takes origin from the cells of the spiral ganglion of the cochlea. Both ganglia consist of bipolar nerve-cells, and from each cell a central fibre passes to the brain, and a peripheral fibre to the internal ear.

Fig. 898.—The terminal nuclei of the vestibular nerve. Schematic. (Testut.)

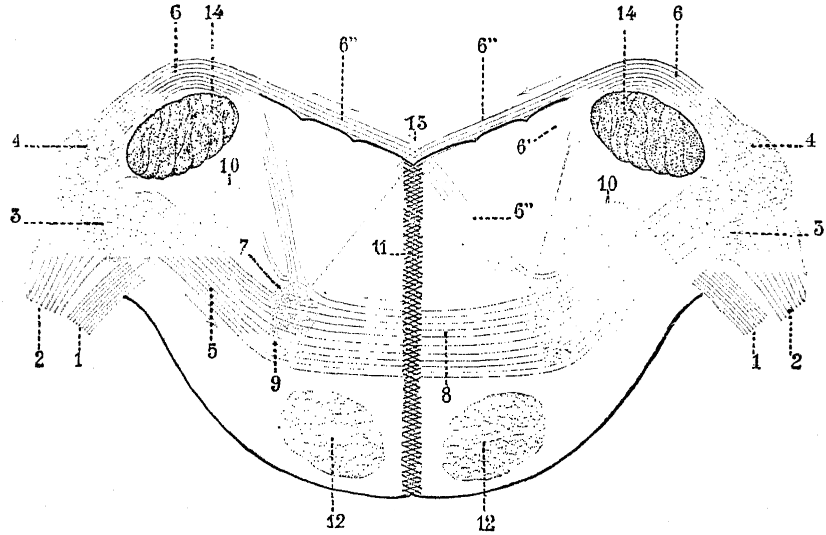


1. Cochlear nerve. 2. Accessory cochlear nucleus. 3. Lateral cochlear nucleus. 4. Vestibular nerve. 5. Medial or chief vestibular nucleus. 6. Nucleus of Deiters. 7. Nucleus of Bechterew. 8. Descending fibres of vestibular nerve. 9. Fibres passing to cerebellum. 10. Fibres going to raphe. 11. Fibres taking an oblique course. 12. Lemniscus. 13. Spinal tract of trigeminal. 14. Cerebrospinal fasciculus. 15. Raphe. 16. Fourth ventricle. 17. Restiform body. 18. Origin of striæ medullares.

Vestibular nerve (fig. 898).—The fibres of the vestibular nerve enter the brain medial to, and on a higher level than, those of the cochlear nerve. They

pass backwards through the pons between the restiform body and the spinal tract of the trigeminal nerve and divide into ascending and descending branches which mostly end in the vestibular nuclei. These nuclei consist of: (1) The *medial or chief vestibular nucleus*, situated in the area acustica of the rhomboid fossa, and crossed dorsally by the striæ medullares (striæ acusticæ): this nucleus is triangular on transverse section, and its lower pat constitutes (2) the *descending or spinal vestibular nucleus*. (3) The *lateral vestibular nucleus* (nucleus of Deiters), and (4) the *superior vestibular nucleus* (nucleus of Bechterew) lie close to the restiform body, and the former contains large mutipolar cells. Some of the ascending fibres of the vestibular nerve end in the vestibular nuclei, but others pass directly to the roof nucleus (nucleus fastigii) and cortex of the opposite side of the cerebellum, and are accompanied by fibres which originate in the cells of the vestibular nuclei. From the cells of the vestibular nuclei

FIG. 899.—The terminal nuclei of the cochlear nerve. Schematic. (Testut.)



The vestibular nerve with its terminal nuclei and their efferent fibres have been suppressed. On the other hand, in order not to obscure the trapezoid body, the efferent fibres of the terminal nuclei on the right side have been resected in a considerable portion of their extent. The trapezoid body, therefore, shows only one-half of its fibres, viz. those which come from the left.

1. Vestibular nerve, divided at its entrance into the medulla oblongata. 2. Cochlear nerve. 3. Ventral or accessory cochlear nucleus. 4. Lateral cochlear nucleus. 5. Efferent fibres of accessory cochlear nucleus. 6. Efferent fibres of lateral cochlear nucleus, forming the striæ medullares, with 6′, their direct bundle going to the superior olivary nucleus of the same side; 6″, their decussating bundles going to the superior olivary nucleus of the opposite side. 7. Superior olivary nucleus. 8. Trapezoid body. 9. Trapezoid nucleus. 10. Central acoustic tract (lateral lemniscus). 11. Raphe. 12. Cerebrospinal fasciculus. 13. Fourth ventricle. 14. Restiform body.

fibres ascend in the medial longitudinal fasciculus and end in the nuclei of the oculomotor, trochlear and abducent nerves. The descending branches of the vestibular nerve end around the cells of the medial and spinal nuclei and constitute the *spinal root* of the nerve. An important strand of descending fibres, the vestibulospinal fasciculus, springs from the cells of Deiters' nucleus and runs downwards in the anterior funiculus of the medulla spinalis (p. 794).

Cochlear nerve (fig. 899).—The cochlear nerve is placed lateral to the vestibular nerve. Its fibres end in two nuclei: one, the *ventral or accessory cochlear nucleus*, lies on the ventral surface of the restiform body; the other, the *lateral cochlear nucleus*, lies on the lateral surface of the restiform body.

The cells of the accessory cochlear nucleus give origin to fibres which run transversely in the pons and constitute the trapezoid body; some of these fibres end around the cells of the superior olivary nucleus or of the trapezoid nucleus of the same or opposite side, but most of them ascend on the lateral side of the superior olivary nucleus under the name of the *lateral lemniscus*. The striæ medullares (striæ acusticæ) are the axons of cells of the lateral cochlear nucleus. They pass over the restiform body, and across the rhomboid fossa

to the median sulcus. Here they dip into the substance of the pons, where some end around the cells of the superior olivary nuclei of both sides, while others, both direct and crossed, pass into the lateral lemniscus.

The lateral lemniscus ascends through the pons, and appears on the surface in the lateral sulcus of the midbrain; its fibres end in the inferior colliculus and the medial geniculate body. In the upper part of the lateral lemniscus there is a collection of nerve-cells, the *nucleus of the lateral lemniscus*, around the cells of which some of the fibres arborise, and from the cells of which fibres originate and are continued upwards into the tract of the lateral lemniscus. From the cells of the medial geniculate body new fibres arise and run through the occipital part of the internal capsule to reach the cortical acoustic centre which is placed in the anterior part of the transverse temporal gyrus, and in the upper part of the middle one-third of the superior temporal gyrus.

The acoustic nerve is soft in texture, and destitute of neurolemma. After leaving the medulla oblongata it passes forwards across the posterior border of the brachium pontis, in company with the facial nerve, from which it is partially separated by the internal auditory artery. It then enters the internal acoustic meatus with the facial nerve. At the bottom of the meatus it receives one or two filaments from the facial nerve, and splits into its *cochlear* and *vestibular* parts, the distribution of which will be described with the anatomy of the internal ear.

Applied Anatomy.—The acoustic nerve is frequently injured, together with the facial nerve, in fracture of the middle fossa of the base of the skull implicating the internal acoustic meatus. The nerve may be either torn across, producing permanent deafness, or it may be bruised or pressed upon by extravasated blood or inflammatory exudation, when the deafness will in all probability be temporary. The nerve may also be injured by violent blows on the head without any fracture of the bones of the skull taking place, and deafness may arise from loud explosions from dynamite, &c., probably from some lesion of this nerve, which is more liable to be injured than the other cerebral nerves on account of its structure. 'Nerve-deafness,' as contrasted with deafness due to changes in the middle ear or meatus, is suggested if (1) a sounding tuning-fork placed on the middle-line of the head is heard better (Weber's test) by the unaffected ear; or if (2) the sounding tuning-fork is heard longer when held before the affected ear (=air conduction) than when it is stood on the corresponding mastoid (=bone conduction, Rinne's test); or if (3) the sounding tuning-fork applied to the vertex or mastoid is heard less well when the air in the meatus is compressed by the use of a Siegle's speculum (Gellé's test); or if (4) the tuning-fork placed on the mastoid is heard for a shorter time than its sound is perceptible to a normal individual (=evidence that bone conduction is diminished, Schwabach's test). It must be remembered that all these tests are liable to anomalies and exceptions, and are not applicable to old people. If, however, concordant results are yielded by the tests of Weber, Rinne, and Gellé, Bezold's 'triad of symptoms,' nerve-deafness rather than deafness due to disease of the conducting structures, is rendered highly probable.

Tinnitus aurium, or the hearing of sounds in the ear that have no objective cause outside the body, is said to be present in as many as sixty per cent. of cases of ear disease of all sorts, and is commonest in disease of the labyrinth or of the nerve. It is very variable in intensity; the worst forms are purely subjective and due to irritation of the nerve itself. The sounds heard are of the most varied nature—buzzing, hissing, whistling, rushing, bell-ringing, and so forth—and may occupy the patient's attention so completely that he is no longer able to attend to his business; he may even commit suicide in order to escape from them. In the insane, tinnitus is associated with delusions and hallucinations of hearing; cases of insanity have even been recorded in which cure was effected by the removal of cerumen impacted in the meatus and giving rise to persistent tinnitus.

The Glossopharyngeal Nerve (figs. 900, 901, 902)

The **glossopharyngeal nerve** contains motor and sensory fibres. It supplies motor fibres to the Stylopharyngeus, and sensory fibres to the pharynx, the palatine tonsil, and the posterior part of the tongue; it is also the nerve of taste for this part of the tongue. It is attached by three or four filaments to the upper part of the medulla oblongata, in the groove between the olive and the restiform body.

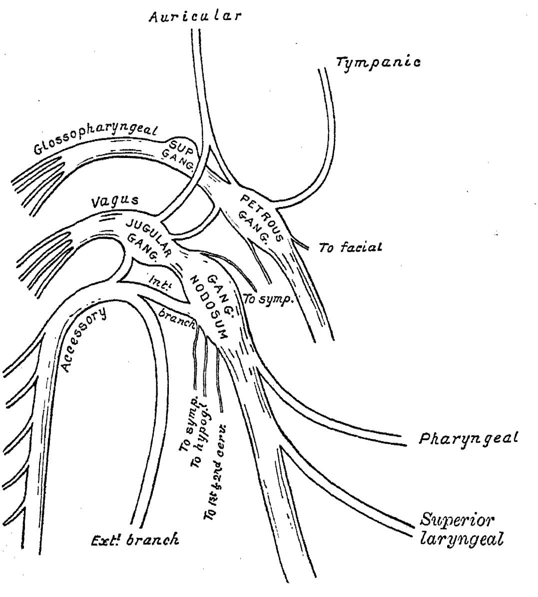
The *sensory* fibres arise from the cells of the superior and petrous ganglia, which are situated on the trunk of the nerve, and will be presently described. When traced into the medulla, some of the sensory fibres end by arborising

around the cells of the upper part of a nucleus which lies beneath the ala cinerea in the lower part of the rhomboid fossa. Most, however, contribute to form a strand, named the *fasciculus solitarius*, which descends in the medulla oblongata. Associated with this strand are numerous nerve-cells (nucleus tractus solitarii) and around these cells the fibres of the fasciculus end.

The *motor* fibres spring from the cells of the *nucleus ambiguus*, which also gives origin to the motor fibres of the vagus nerve, and to the cerebral part of the accessory nerve. This nucleus lies some distance from the surface of the rhomboid fossa in the lateral part of the medulla oblongata and is continuous below with the anterior grey column of the medulla spinalis. From the nucleus the fibres are first directed backwards towards the rhomboid fossa, and then forwards and lateralwards to join with the fibres of the sensory root.

From the medulla oblongata, the glossopharyngeal nerve passes forwards and lateralwards towards the triangular depression into which the aquæductus cochleæ opens, on the inferior surface of the petrous portion of the temporal bone. It lies at first under cover of the flocculus, and rests on the tuberculum jugulare of the occipital bone, which is sometimes grooved by it. It leaves the skull by bending sharply downwards through the central part of the jugular foramen, anterior and lateral to the vagus and accessory nerves, and in a separate sheath of dura mater (fig. 901). In its transit through the jugular foramen it is lodged in a deep groove leading from the triangular depression for the aquæductus cochleæ, and here it is separated by the inferior petrosal sinus from the vagus and accessory nerves. The deep groove is converted into a canal by a bridge which is usually composed of fibrous tissue, but which consists of bone in about 25 per cent. of skulls.* At its exit from the skull it passes forwards between the internal jugular vein and internal carotid artery; it descends in front of the latter vessel, and beneath the styloid process and the muscles connected with it, to the lower border of the Stylopharyngeus. It then curves forwards, forming an arch on the side of the neck and lying upon the Stylopharyngeus and Constrictor pharyngis medius. Thence it passes under cover of the Hyoglossus, and is finally distributed to the palatine tonsil, the mucous membrane of the pharynx and the posterior part of the tongue, and the mucous glands of the mouth.

Fig. 900.—A plan of the upper portions of the glossopharyngeal, vagus, and accessory nerves.



Two ganglia, the superior and the petrous, are situated on that portion of the nerve which traverses the jugular foramen (fig. 900).

The **superior ganglion** (jugular ganglion) is situated in the upper part of the groove in which the nerve is lodged during its passage through the jugular foramen. It is very small, and is usually regarded as a detached portion of the petrous ganglion.

The **petrous ganglion** is larger than the superior ganglion and is situated in a depression in the lower border of the petrous portion of the temporal bone.

The glossopharyngeal nerve communicates with the sympathetic trunk, and with the vagus and facial nerves.

The petrous ganglion is connected by a filament with the superior cervical

* E. Joyce Partridge, *Journal of Anatomy*, vol. lii.

ganglion of the sympathetic. The branches to the vagus consist of two filaments which arise from the petrous ganglion; one joins the auricular branch, and the other the jugular ganglion, of the vagus. The branch to the facial arises from the trunk of the glossopharyngeal nerve below the petrous ganglion; it perforates the posterior belly of the Digastricus and joins the facial nerve near the stylomastoid foramen.

The *branches of distribution* of the glossopharyngeal nerve are: tympanic, carotid, pharyngeal, muscular, tonsillar, and lingual.

The **tympanic nerve** (Jacobson's nerve) arises from the petrous ganglion of the glossopharyngeal nerve, and ascends to the tympanic cavity through the inferior tympanic canaliculus (p. 212). In the tympanic cavity it divides into branches which form the *tympanic plexus* and are contained in grooves upon the surface of the promontory. This plexus gives off: (1) the lesser superficial petrosal nerve; (2) a branch to join the greater superficial petrosal nerve; and (3) branches to the tympanic cavity, all of which are described with the anatomy of the middle ear.

The **carotid branches** descend along the trunk of the internal carotid artery as far as its origin, communicating with the pharyngeal branch of the vagus, and with branches of the sympathetic trunk.

The **pharyngeal branches** are three or four filaments which unite, opposite the Constrictor pharyngis medius, with the pharyngeal branches of the vagus nerve and the laryngopharyngeal branches of the sympathetic trunk to form the *pharyngeal plexus*; branches from this plexus perforate the muscular coat of the pharynx and are distributed to its muscles and mucous membrane.

The **muscular branch** supplies the Stylopharyngeus.

The **tonsillar branches** supply the palatine tonsil, and form around it a plexus with branches of the middle and posterior palatine nerves; from this plexus filaments are distributed to the soft palate and fauces.

The **lingual branches** are two in number: one supplies the papillæ vallatæ and the mucous membrane near the sulcus terminalis of the tongue; the other supplies the mucous membrane and follicular glands of the posterior one-third of the tongue, and communicates with the lingual nerve.

The Vagus Nerve (figs. 900, 901, 902)

The **vagus nerve** is composed of motor and sensory fibres, and has a more extensive course and distribution than any of the other cerebral nerves, since it passes through the neck and thorax to the abdomen.

The vagus nerve is attached by eight or ten filaments to the medulla oblongata in the groove between the olive and the restiform body, below the glossopharyngeal nerve. The *sensory* fibres arise from the cells of the jugular ganglion and ganglion nodosum of the nerve (see below), and, when traced into the medulla oblongata, mostly end by arborising around the cells of the inferior part of a nucleus which lies beneath the ala cinerea in the lower part of the rhomboid fossa; a few descend in the fasciculus solitarius and end around its cells. The *motor* fibres arise from the cells of the nucleus ambiguus, already referred to in connexion with the motor root of the glossopharyngeal nerve (p. 916).

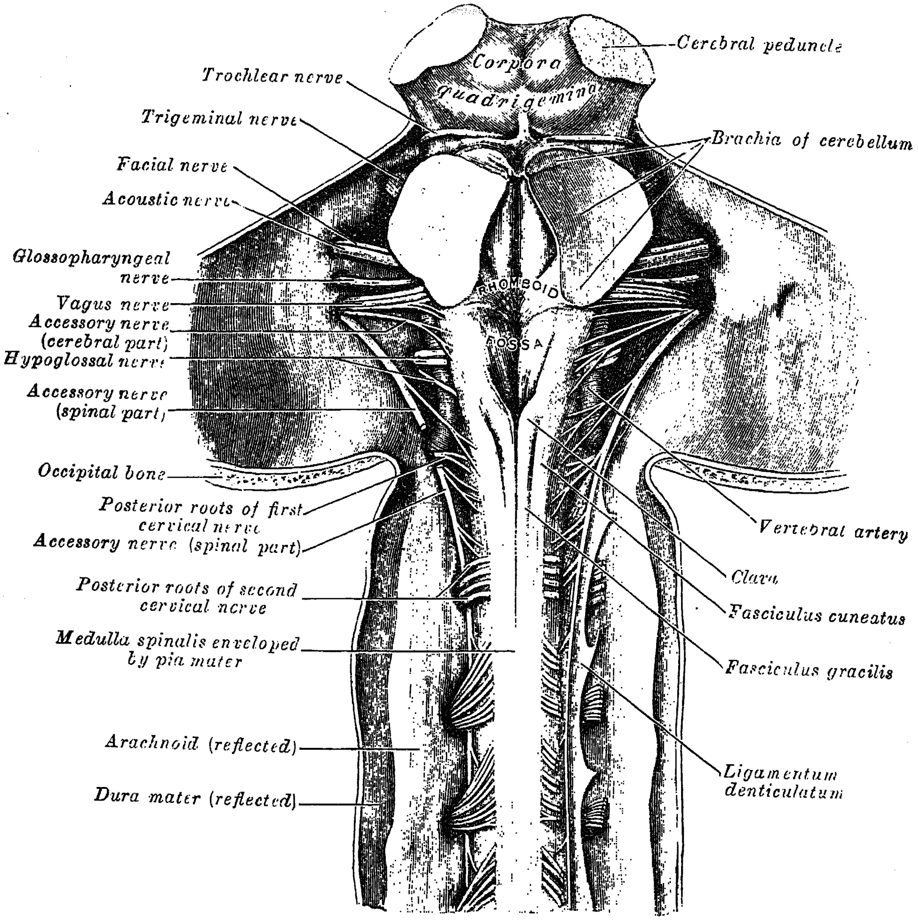
The filaments of the nerve unite, and form a flat cord which passes beneath the flocculus of the cerebellum to the jugular foramen, through which it leaves the cranium. In emerging through this opening, the vagus nerve is accompanied by and contained in the same sheath of dura mater with the accessory nerve, a septum separating them from the glossopharyngeal nerve which lies in front (fig. 901). In this situation the vagus nerve presents a well-marked enlargement, the *jugular ganglion.* After its exit from the jugular foramen the vagus nerve enlarges into a second swelling, the *ganglion nodosum.*

The **jugular ganglion** (ganglion of the root) is of a greyish colour, spherical in form, about 4 mm. in diameter. It is joined by one or two delicate filaments with the cerebral portion of the accessory nerve; it is connected by a twig with the petrous ganglion of the glossopharyngeal nerve, and with the sympathetic trunk by a filament from the superior cervical ganglion; its auricular branch gives off an ascending branch which joins the facial nerve.

The **ganglion nodosum** (ganglion of the trunk) is cylindrical in form, of a reddish colour, and 2·5 cm. long. It is connected with the hypoglossal nerve, the superior cervical ganglion of the sympathetic trunk, and the loop between the first and second cervical nerves. The cerebral portion of the accessory nerve passes over the ganglion and is attached to it by fibrous tissue.

Beyond the ganglion nodosum the cerebral portion of the accessory nerve blends with the vagus nerve; its fibres are principally distributed to the

Fig. 901.—The upper part of the medulla spinalis, and the hind-brain and mid-brain. Exposed from behind.



pharyngeal and superior laryngeal branches of the vagus nerve, but some descend in the trunk of the vagus nerve, to be distributed with the recurrent nerve and probably also with the cardiac nerves.

The vagus nerve passes vertically down the neck within the carotid sheath, lying between the internal jugular vein and internal carotid artery as far as the upper border of the thyreoid cartilage, and then between the same vein and the common carotid artery to the root of the neck. The further course of the nerve differs on the two sides of the body.

On the *right side*, the nerve passes across the first part of the subclavian artery, between it and the right innominate vein, and descends by the side of the trachea to the back of the root of the lung, where it spreads out in the *right posterior pulmonary plexus*. From the lower part of this plexus two cords descend on the œsophagus, and divide to form, with branches from the left nerve, the *œsophageal plexus*. Below, these branches are collected into a

single cord, which runs along the back of the œsophagus, enters the abdomen through the œsophageal opening in the Diaphragm, and is distributed to the postero-inferior surface of the stomach, joining the left side of the cœliac plexus, and sending filaments to the lienal (splenic) plexus.

On the *left side*, the nerve enters the thorax between the left carotid and subclavian arteries, behind the left innominate vein. It crosses the left side of the arch of the aorta, and descends behind the root of the left lung, forming there the *left posterior pulmonary plexus*. From this it runs along the anterior surface of the œsophagus, where it unites with branches of the right nerve in the *œsophageal plexus*, and is continued to the stomach, distributing branches over its anterosuperior surface; some of these extend over the fundus, and others along the lesser curvature. Filaments from these branches enter the lesser omentum, and join the hepatic plexus.

The *branches of distribution* of the vagus nerve are:

In the jugular fossa . . .	Meningeal. Auricular.
In the neck	Pharyngeal. Superior laryngeal. Right recurrent. Superior cardiac.
In the thorax . . .	Inferior cardiac. Left recurrent. Anterior bronchial. Posterior bronchial. Œsophageal.
In the abdomen . . .	Gastric. Cœliac. Hepatic.

The **meningeal branch** springs from the jugular ganglion of the vagus nerve, and is distributed to the dura mater in the posterior fossa of the skull.

The **auricular branch** (nerve of Arnold) also arises from the jugular ganglion of the vagus nerve, and is joined soon after its origin by a filament from the petrous ganglion of the glossopharyngeal; it passes behind the internal jugular vein, and enters the mastoid canaliculus on the lateral wall of the jugular fossa. Traversing the substance of the temporal bone, it crosses the facial canal about 4 mm. above the stylomastoid foramen, and here it gives off an ascending branch which joins the facial nerve. It then passes through the tympanomastoid fissure, and divides into two branches; one joins the posterior auricular nerve, the other is distributed to the skin of the back of the auricula and to the posterior part of the external acoustic meatus.

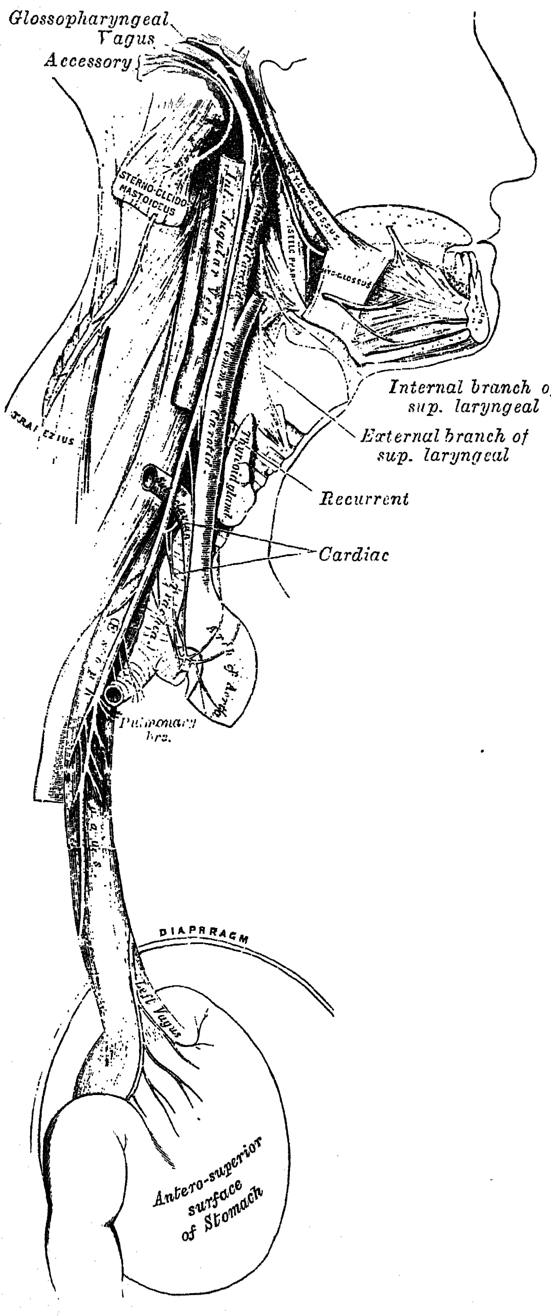
The **pharyngeal branch**, the principal motor nerve of the pharynx, arises from the upper part of the ganglion nodosum of the vagus nerve, and consists principally of filaments from the cerebral portion of the accessory nerve. It passes across the internal carotid artery to the upper border of the Constrictor pharyngis medius, where it divides into numerous filaments which join with branches from the sympathetic trunk, the glossopharyngeal and external laryngeal nerves, to form the *pharyngeal plexus*. From the plexus, branches are distributed to the muscles and mucous membrane of the pharynx, and the muscles of the soft palate, except the Tensor veli palatini. A minute filament joins the hypoglossal nerve as the latter winds round the occipital artery.

The **superior laryngeal nerve**, larger than the preceding, arises from the middle of the ganglion nodosum of the vagus nerve, and in its course receives a branch from the superior cervical ganglion of the sympathetic trunk. It descends, by the side of the pharynx, behind the internal carotid artery and divides into two branches, an internal and an external.

The *internal branch* descends to the hyothyreoid membrane; it pierces this membrane at a higher level than the superior laryngeal artery, and divides into an upper and a lower branch. The upper branch is directed horizontally, and supplies twigs to the mucous membrane of the pharynx, the epiglottis, the vallecula of the tongue and the vestibule of the larynx. The lower branch descends in the medial wall of the recessus piriformis, and gives branches to the aryepiglottic fold, and to the mucous membrane on the back of the arytænoid

cartilage. It also supplies one or two branches to the Arytænoideus muscle, and these branches unite with twigs from the recurrent nerve to the same muscle; the Arytænoideus has therefore a double nerve-supply. The internal branch of the superior laryngeal nerve ends by piercing the Constrictor pharyngis inferior, and joining with the recurrent nerve.*

Fig. 902.—The course and distribution of the glossopharyngeal, vagus, and accessory nerves.



The *external branch*, the smaller, descends beneath the Sternothyreoideus; it lies at first on the Constrictor pharyngis inferior, and then passing deep to that muscle, winds round the inferior thyreoid tubercle and enters the Cricothyreoideus. It gives branches to the pharyngeal plexus and to the Constrictor pharyngis inferior; behind the common carotid artery it communicates with the superior cardiac nerve.

The **recurrent nerve** (recurrent laryngeal nerve) differs, as to its origin and course, on the two sides of the body. On the *right* side it arises from the vagus nerve in front of the first part of the subclavian artery; it winds from before backwards round that vessel, and ascends obliquely to the side of the trachea behind the common carotid artery, and either in front of or behind the inferior thyreoid artery. On the *left* side, it arises from the vagus nerve on the left of the arch of the aorta, and winds below the arch immediately behind the attachment of the ligamentum arteriosum to the concavity of the arch, and then ascends to the side of the trachea. The nerve on either side ascends in the groove between the trachea and œsophagus,† passes under the lower border of the Constrictor pharyngis inferior, and enters the larynx behind the articulation of the inferior

* Consult an article on 'The nerves of the human larynx' by T. F. M. Dilworth, *Journal of Anatomy*, vol. lvi.

† F. G. Parsons (*Journal of Anatomy*, vol. liv.) points out that the right nerve may lie at some little distance from the groove between the trachea and the œsophagus.

cornu of the thyreoid with the cricoid cartilage; it gives branches to all the muscles of the larynx, excepting the Cricothyreoideus. It communicates with the internal branch of the superior laryngeal nerve, and gives a few filaments to the mucous membrane of the lower part of the larynx.

As the recurrent nerve hooks round the subclavian artery, or the arch of the aorta, it gives several cardiac filaments to the deep part of the cardiac plexus. As it ascends in the neck it gives branches, more numerous on the left than on the right side, to the mucous membrane and muscular coat of the œsophagus; branches to the mucous membrane and muscular fibres of the trachea; and some filaments to the Constrictor pharyngis inferior.

The **superior cardiac branches**, two or three in number, arise from the vagus nerve, at the upper and lower parts of the neck. The *upper branches* are small, and join with the cardiac branches of the sympathetic trunk. They can be traced to the deep part of the cardiac plexus.

The *lower branches* arise at the root of the neck. That from the right vagus passes in front or by the side of the innominate artery, and proceeds to the deep part of the cardiac plexus; that from the left runs down across the left side of the arch of the aorta, and joins the superficial part of the cardiac plexus.

The **inferior cardiac branches**, on the right side, arise from the trunk of the vagus nerve as it lies by the side of the trachea, and from its recurrent nerve; on the left side from the recurrent nerve only. They end in the deep part of the cardiac plexus.

The **anterior bronchial branches**, two or three in number, and of small size, are distributed on the anterior surface of the root of the lung. They join with filaments from the sympathetic, and form the *anterior pulmonary plexus*.

The **posterior bronchial branches**, more numerous and larger than the anterior, are distributed on the posterior surface of the root of the lung; they are joined by filaments from the third and fourth (sometimes also from the first and second) thoracic ganglia of the sympathetic trunk, and form the *posterior pulmonary plexus*. Branches from this plexus accompany the ramifications of the bronchi through the substance of the lung.

The **œsophageal branches** are given off both above and below the bronchial branches; the lower are more numerous and larger than the upper. They form, together with branches from the opposite nerve, the *œsophageal plexus*. From this plexus filaments are distributed to the œsophagus and to the back of the pericardium.

The **gastric branches** are distributed to the stomach. The right vagus forms the *posterior gastric plexus* on the postero-inferior surface of the stomach, and the left the *anterior gastric plexus* on the anterosuperior surface.

The **cœliac branches** are mainly derived from the right vagus: they join the cœliac plexus and through it supply branches to the pancreas, spleen, kidneys, suprarenal glands, and intestine.

The **hepatic branches** arise from the left vagus: they join the hepatic plexus and through it are conveyed to the liver.

Applied Anatomy.—The trunk of the vagus is rarely injured, but the functions of the nerve may be interfered with by damage to its nucleus of origin in the medulla; by thickening or growth from the meninges or bones, or aneurysm of the basilar artery, before its exit from the skull; injuries such as gunshot or punctured wounds in the neck, or injuries during such operations as ligature of the carotid artery, removal of tuberculous glands or other deep-seated tumours. The vagus may also be compressed by aneurysms of the carotid artery, and its deep origin becomes affected in bulbar paralysis. The symptoms produced by paralysis of the nerve are palpitation, with increased frequency of the pulse, constant vomiting, slowing of the respiration, and a sensation of suffocation.

'Reflexes' on the branches of the vagus are not at all uncommonly met with. The 'ear cough' is perhaps one of the commonest, where a plug of wax in the acoustic meatus may, by irritating the filaments of the auricular (Arnold's) nerve, be responsible for a persistent cough. Syringing the external acoustic meatus frequently produces cough, and, in children, vomiting is not uncommon as the result of such a procedure; moreover, in people with weak hearts, syringing the ear has been responsible for a sudden fatal syncope, by reflex irritation of the cardiac branches. Another very common example is the persistent cough which is frequently due to enlarged bronchial glands in children, the irritation of which is referred to the superior laryngeal filaments.

The anatomy of the laryngeal nerves is of importance in considering some of the morbid conditions of the larynx. When the peripheral terminations of the superior laryngeal nerve are irritated by some foreign body passing over them, reflex spasm of

the glottis is the result. When its trunk is pressed upon by, for instance, a goitre or an aneurysm of the upper part of the carotid, there is a peculiar dry, brassy cough. When the nerve is paralysed, there is anæsthesia of the mucous membrane of the larynx, so that foreign bodies can readily enter the cavity, and, as the nerve also supplies the Crico-thyreoideus muscle, the vocal folds cannot be made tense, and the voice is deep and hoarse. Paralysis may be the result of bulbar paralysis; may be a sequel to diphtheria, when both nerves are usually involved; or it may, though less commonly, be caused by the pressure of tumours or aneurysms, when the paralysis is generally unilateral. Irritation of the recurrent nerves produces spasm of the muscles of the larynx. When both recurrent nerves are paralysed, the vocal folds are motionless, in the so-called 'cadaveric position'—that is to say, in the position in which they are found in ordinary tranquil respiration; neither closed as in phonation, nor widely open as in deep inspiratory efforts. When one recurrent nerve is paralysed, the vocal fold of the same side is motionless, while the opposite one crosses the middle line to accommodate itself to the affected one; hence phonation is possible, but the voice is altered and weak in timbre. The nerves may be paralysed in bulbar paralysis or after diphtheria, when the paralysis usually affects both sides; or they may be affected by the pressure of aneurysms of the aorta, innominate, or subclavian arteries; by mediastinal tumours; by gummata; or by cancer of the upper part of the œsophagus, when the paralysis is often unilateral. Paralysis of the adductor muscles of the larynx on both sides is quite common, and is usually functional in nature. The voice is reduced to a whisper, but the power of coughing is preserved.

The Accessory Nerve (figs. 900, 901, 902)

The **accessory nerve** (spinal accessory nerve) consists of two parts, a cerebral and a spinal.

The **cerebral part** is the smaller; its fibres arise from the cells of the nucleus ambiguus and emerge as four or five delicate rootlets from the side of the medulla oblongata, below the roots of the vagus. It runs lateralwards to the jugular foramen, where it interchanges fibres with the spinal portion or becomes united to it for a short distance; here it is also connected by one or two filaments with the jugular ganglion of the vagus. It passes through the jugular foramen, separates from the spinal portion, and is continued over the ganglion nodosum of the vagus, to the surface of which it is adherent, and is distributed principally to the pharyngeal and superior laryngeal branches of the vagus. Through the pharyngeal branch of the vagus it supplies the muscles of the soft palate, with the exception of the Tensor veli palatini. Some filaments from it are continued into the trunk of the vagus below the ganglion, to be distributed with the recurrent nerve and probably also with the cardiac nerves.

The **spinal part** is firm in texture, and its fibres arise from the motor cells in the lateral part of the anterior column of the grey substance of the medulla spinalis as low as the fifth cervical nerve. Passing through the lateral white funiculus of the medulla spinalis, they emerge on its surface and unite to form a trunk, which ascends between the ligamentum denticulatum and the posterior roots of the spinal nerves, and enters the skull through the foramen magnum, behind the vertebral artery. It is then directed upwards and lateralwards to the jugular foramen, through which it passes in the same sheath of dura mater as the vagus nerve, but separated from that nerve by a fold of the arachnoid. In the jugular foramen, it receives one or two filaments from the cerebral part of the accessory nerve, or else joins it for a short distance and then parts from it again. At its exit from the jugular foramen, it runs backwards over the internal jugular vein in about 66 per cent. of subjects, and under it in about 33 per cent. (Tandler). The nerve then descends obliquely behind the Digastricus and Stylohyoideus to the upper part of the Sternocleidomastoideus; it pierces this muscle, and courses obliquely across the posterior triangle of the neck, to end in the deep surface of the Trapezius. As it traverses the Sternocleidomastoideus it gives several filaments to the muscle, and joins with branches from the second cervical nerve. In the posterior triangle it unites with the second and third cervical nerves, while beneath the Trapezius it forms a plexus with the third and fourth cervical nerves, and from this plexus fibres are distributed to the muscle.

Applied Anatomy.—The functions of the accessory nerve may be interfered with either by central changes; or at its exit from the skull, by fractures running across the jugular foramen; or in the neck, by inflamed lymph-glands, &c. The acute wry-neck in children

is most commonly due to inflamed or suppurating glands, and rapidly subsides with appropriate treatment. Central irritation causes clonic spasm of the Sternocleidomastoideus and Trapezius muscles, or, as it is termed, spasmodic torticollis. In cases of this affection in which all previous palliative treatment has failed, and the spasms are so severe as to undermine the patient's health, division or excision of a portion of the accessory nerve has been resorted to. This must be done from the anterior border of the Sternocleidomastoideus (fig. 662, p. 608). The operation consists in making an incision, 8 cm. in length, from the apex of the mastoid process along the anterior border of the muscle, which is defined and pulled backwards so as to stretch the nerve, which is then to be sought beneath the Digastricus, about 5 cm. below the apex of the mastoid process. Unfortunately, the operation does not yield a satisfactory or permanent cure, as the spasms tend to recur after an interval, either in the same muscles or in other groups of neck muscles.

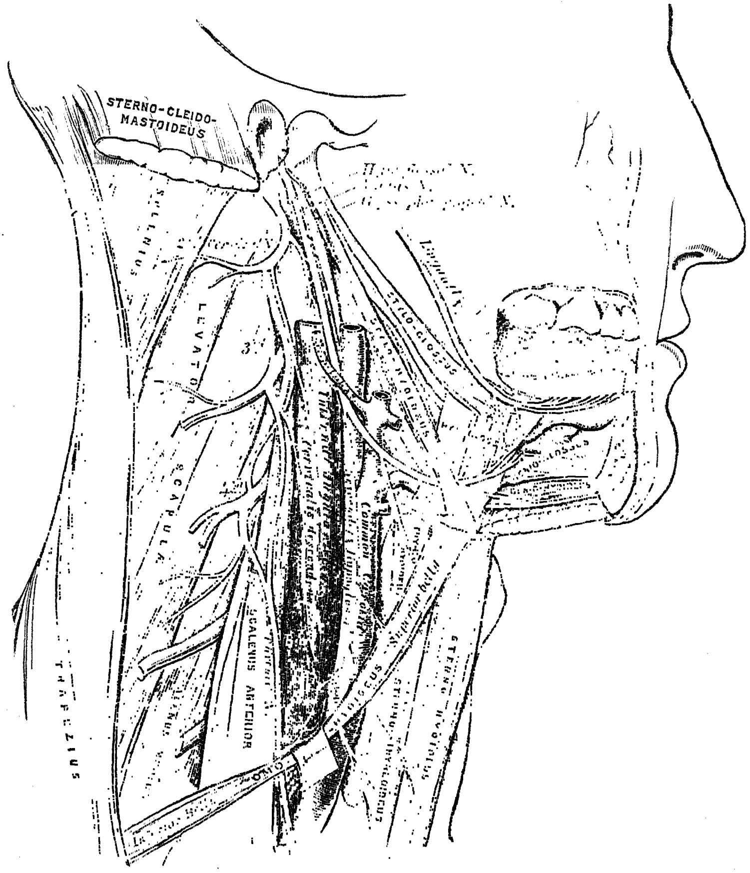
In cases where extensive dissections are undertaken for enlarged glands in the neck, it is essential that this nerve should be at once sought and isolated from the mass of inflamed glands so as to maintain its continuity.

The Hypoglossal Nerve (figs. 903, 904)

The **hypoglossal nerve** is the motor nerve of the tongue.

Its fibres arise from the cells of the hypoglossal nucleus, which is an upward prolongation of the base of the anterior column of grey substance of the medulla

Fig. 903.—The right hypoglossal nerve and cervical plexus.

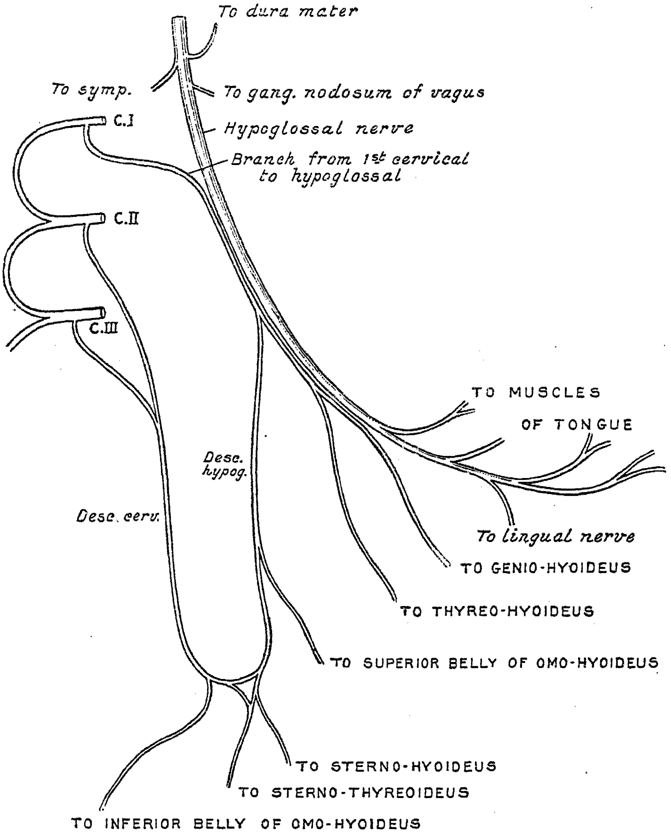


spinalis. This nucleus is about 2 cm. long, and its upper part corresponds with the trigonum hypoglossi, or lower portion of the medial eminence of the rhomboid fossa (p. 824). The lower part of the nucleus extends downwards into the closed part of the medulla oblongata, and there lies in relation to the ventrolateral aspect of the central canal. The fibres run forwards through

the medulla oblongata, and emerge in the anterolateral sulcus between the pyramid and the olive.

The rootlets of this nerve run lateralwards behind the vertebral artery, and are collected into two bundles, which perforate the dura mater separately, opposite the hypoglossal canal in the occipital bone, and unite together after their passage through it; in some cases the canal is divided into two by a small bony spicule. The nerve descends almost vertically to a point corresponding with the angle of the mandible. It is at first deeply seated beneath the internal carotid artery and internal jugular vein, and intimately connected with the vagus nerve; it then passes forwards

Fig. 904.—A plan of the hypoglossal nerve.



between the vein and artery, and lower down in the neck becomes superficial below the Digastricus. The nerve then loops round the occipital artery, and crosses the external carotid and lingual arteries. It passes beneath the tendon of the Digastricus, the Stylohyoideus, and the Mylohyoideus, lying between the last-named muscle and the Hyoglossus, and is then continued forwards in the fibres of the Genioglossus as far as the tip of the tongue, distributing branches to its muscular substance. It communicates with the sympathetic trunk, and with the vagus, first and second cervical, and lingual nerves.

Opposite the atlas the nerve receives branches from the superior cervical ganglion of the sympathetic trunk, and at the same level is joined by a filament from the loop connecting the first and second cervical nerves.

The communications with the vagus nerve take place close to the skull, numerous filaments passing between the hypoglossal nerve and the ganglion nodosum of the vagus nerve through the mass of connective tissue which unites the two nerves. As the nerve winds round the occipital artery it gives off a filament to the pharyngeal plexus.

Near the anterior border of the Hyoglossus it is united to the lingual nerve by numerous filaments which ascend upon the muscle.

The *branches of distribution* of the hypoglossal nerve are :

Meningeal.	Thyreohyoid.
Descending.	Muscular.

Of these branches the meningeal, descending, thyreohyoid, and that to the Geniohyoideus, are probably derived mainly from the branch which passes from the loop between the first and second cervical nerves to join the hypoglossal (fig. 904).

Meningeal branches.—As the hypoglossal nerve passes through the hypoglossal canal it supplies several filaments to the dura mater in the posterior fossa of the skull.

The **descending ramus**, long and slender, quits the hypoglossal nerve where the latter turns round the occipital artery, and descends in front of or within the sheath of the carotid vessels ; it gives a branch to the superior belly of the Omohyoideus, and, just below the middle of the neck, joins the communicantes cervicales from the second and third cervical nerves to form a loop, the *ansa hypoglossi*. From the convexity of this loop branches pass to supply the Sternohyoideus, the Sternothyreoideus, and the inferior belly of the Omohyoideus. According to Arnold, another filament descends in front of the vessels into the thorax, and joins the cardiac and phrenic nerves.

The **thyreohyoid branch** arises from the hypoglossal nerve near the posterior border of the Hyoglossus ; it runs obliquely across the greater cornu of the hyoid bone, and supplies the Thyreohyoideus muscle.

The **muscular branches** are distributed to the Styloglossus, Hyoglossus, Geniohyoideus, and Genioglossus. Numerous slender branches pass upwards into the substance of the tongue to supply its intrinsic muscles.

Applied Anatomy.—The hypoglossal nerve is an important guide in the operation of ligature of the lingual artery (p. 612). It runs forwards on the Hyoglossus just above the greater cornu of the hyoid bone, and forms the upper boundary of the triangular space in which the artery is to be sought by cutting through the fibres of the Hyoglossus. In cases where the nerve is involved by gumma or new growth of the base of the skull, or where it has been injured on one side of the neck, or in some cases of bulbar paralysis, unilateral paralysis, together with hemiatrophy of the tongue, results; the tongue, when protruded, being directed to the paralysed side owing to the unopposed action of the Genioglossus of the opposite side. On retraction, the wasted and paralysed side of the tongue rises up higher than the other. The larynx may deviate towards the sound side on swallowing, from the unilateral paralysis of the depressors of the hyoid bone. If the paralysis is bilateral, e.g. the result of a bullet wound of the infrahyoid region, the tongue lies motionless in the mouth, taste and tactile sensibility of the organ are perfect, articulation is slow and sticky; swallowing is very difficult, and the patient has to throw his head backwards and push the bolus of food back into the pharynx with his finger before he can swallow it.

THE SPINAL NERVES

The **spinal nerves** spring from the medulla spinalis, and pass through the intervertebral foramina. They number thirty-one pairs, which are grouped as follows : cervical, 8 ; thoracic, 12 ; lumbar, 5 ; sacral, 5 ; coccygeal, 1.

The first cervical nerve emerges from the vertebral canal between the occipital bone and the atlas vertebra, and is therefore called the *suboccipital nerve* ; the eighth issues between the seventh cervical and first thoracic vertebræ.

Nerve-roots.—Each nerve is attached to the medulla spinalis by an anterior and a posterior root (p. 797), the latter being characterised by the presence of a ganglion, the *spinal ganglion*.

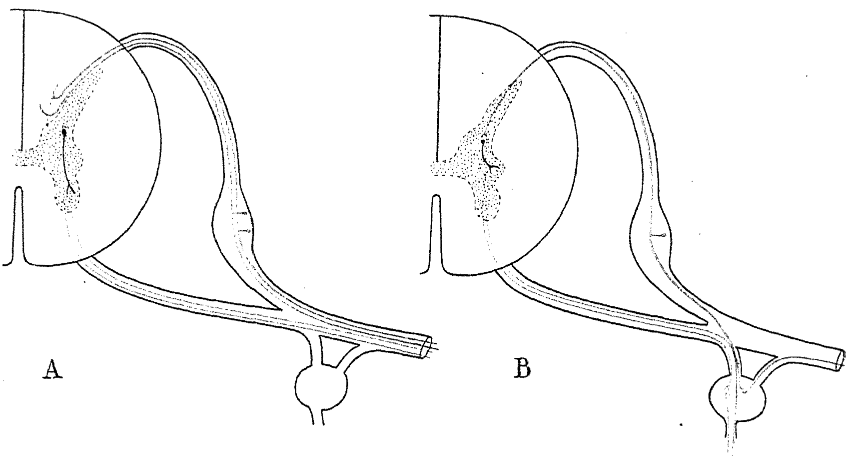
The **anterior root** emerges from the anterior surface of the medulla spinalis as a number of rootlets or filaments (fila radicularia), which coalesce to form two bundles near the intervertebral foramen.

The **posterior root** (except in the case of the first cervical nerve) is larger than the anterior ; its rootlets are attached along the posterolateral furrow of the medulla spinalis and unite to form two bundles which join the spinal ganglion.

The **spinal ganglia** are collections of nerve-cells on the posterior roots of the spinal nerves. Each ganglion is oval in shape, reddish in colour, and

its size bears a proportion to that of the nerve-root on which it is situated; it is bifid medially where it is joined by the two bundles of the posterior nerve-root. The ganglia are usually placed in the intervertebral foramina, immediately outside the points where the nerve-roots perforate the dura mater, but

FIG. 905.—Sketches showing the central connexions of the somatic fibres (A) and autonomic fibres (B) of a typical spinal nerve. The efferent fibres are represented by *red*, and the afferent fibres by *blue*, lines.



the ganglia of the first and second cervical nerves lie on the vertebral arches of the atlas and epistropheus, and those of the sacral nerves are inside the vertebral canal, and that of the coccygeal nerve is within the sheath of dura mater.

Structure.—The ganglia consist chiefly of unipolar nerve-cells, and from these the fibres of the posterior root take origin; the single process of each cell divides after a short course into a central fibre which enters the medulla spinalis and a peripheral fibre which runs into the spinal nerve (fig. 906). Two other forms of cells are said to be present, viz.: (*a*) the cells of Dogiel, whose axons ramify close to the cell (type II. of Golgi) and are distributed entirely within the ganglion; and (*b*) multipolar cells similar to those found in the sympathetic ganglia.

The ganglia of the first pair of cervical nerves may be absent, while small *aberrant ganglia* consisting of groups of nerve-cells are sometimes found on the posterior roots of the upper cervical nerves between the spinal ganglia and the medulla spinalis.

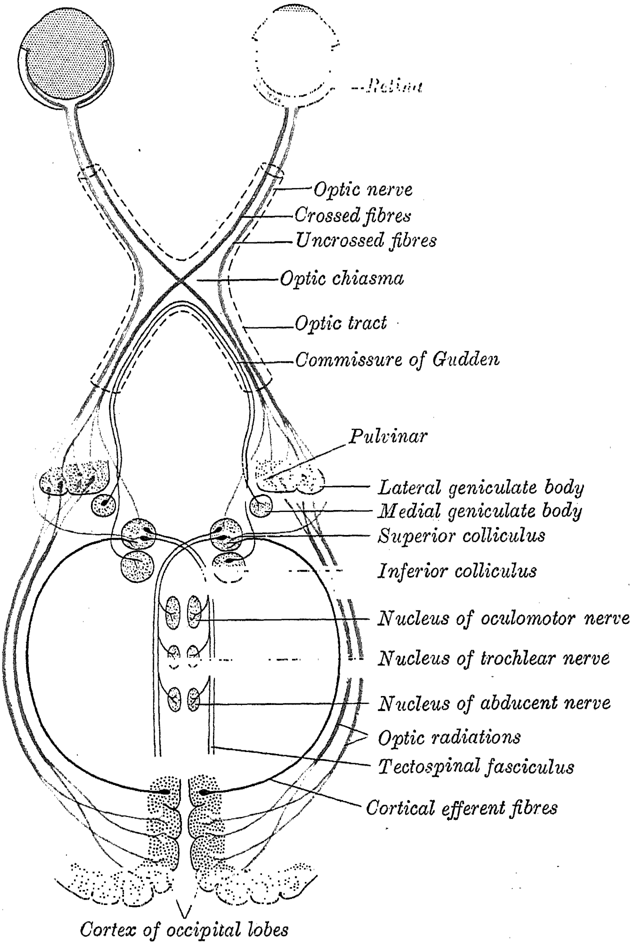
Each nerve-root receives a covering from the pia mater, and is loosely invested by the arachnoid, the latter being prolonged as far as the points where the roots pierce the dura mater. The two roots pierce the dura mater separately, each receiving a sheath from this membrane; where the roots join to form the spinal nerve this sheath is continuous with the epineurium of the nerve.

Size and direction.—The roots of the upper four *cervical* nerves are small, those of the lower four are large. The posterior roots of the cervical nerves bear a proportion to the anterior of three to one, which is greater than in the other regions; their individual filaments are also larger than those of the anterior roots. The posterior root of the first cervical is an exception to this, being smaller than the anterior root; in about eight per cent. of cases it is wanting. The roots of the first and second cervical nerves are short, and run nearly horizontally to their points of exit from the vertebral canal. From the third to the eighth cervical they are directed obliquely downwards, the obliquity and length of the roots successively increasing; the distance, however, between the level of attachment of any of these roots to the medulla spinalis and the points of exit of the corresponding nerves never exceeds the height of one vertebra.

The roots of the *thoracic* nerves, with the exception of the first, are of small size, and the posterior roots only slightly exceed the anterior in thickness. They increase successively in length, from above downwards, and, in the lower

The **optic chiasma or commissure**, formed by the union of the two optic nerves, is somewhat quadrilateral in shape; it lies above the tuberculum sellæ and the anterior part of the diaphragma sellæ, some distance behind the so-called sulcus chiasmatis of the sphenoidal bone. It forms the anterior part of the floor of the third ventricle and is in relation above with the lamina terminalis, below with the cisterna chiasmatis which separates it from the anterior part

Fig. 878.—A scheme showing the central connexions of the optic nerves and optic tracts.



of the diaphragma sellæ, in front with the anterior cerebral and anterior communicating arteries, behind with the tuber cinereum, and laterally with the anterior perforated substance and the internal carotid artery.

The fibres of the optic nerves undergo a partial decussation in the optic chiasma (fig. 878). The fibres from the medial (nasal) half of each retina cross the middle line in the central part of the chiasma and enter the optic tract of the opposite side. The fibres from the lateral (temporal) half of each retina do not cross, but are continued backwards, through the lateral part of the chiasma, into the optic tract of the same side. The posterior part of the chiasma consists of fibres which cross the middle line, but do not form parts of the optic nerves; these fibres connect the medial geniculate body of one side with the inferior colliculus of the opposite side, and constitute what is known as the *commissure of Gudden.*

1. The *somatic efferent* fibres originate in the cells of the anterior grey column of the medulla spinalis, and run outwards through the anterior nerve-roots to the spinal nerve. They convey impulses to the voluntary muscles, and are continuous from their origin to their peripheral distribution. The *somatic afferent* fibres convey impressions inwards from the skin, &c., and originate in the unipolar nerve-cells of the spinal ganglia. The single processes of these cells divide into peripheral and central fibres, and the latter enter the medulla spinalis through the posterior nerve-roots.

2. The *autonomic* fibres are also efferent and afferent. The *efferent or preganglionic* fibres originate in the lateral column of the medulla spinalis, and are conveyed through the anterior nerve-root and the white ramus communicans. Those issuing from the thoracic and lumbar regions of the medulla spinalis are part of the *sympathetic* system and pass to the corresponding ganglion of the sympathetic trunk; here they may end by forming synapses around its cells, or may run through the ganglion to end in another of the ganglia of the sympathetic trunk, or in a more distally placed ganglion in one of the sympathetic plexuses. In all cases they end by forming synapses around other nerve-cells. From the cells of the ganglia of the sympathetic trunk other fibres (*postganglionic*) take origin; some of these run through the grey rami communicantes to join the spinal nerves, while others pass to the viscera, either directly or after interruption in one of the distal ganglia. The fibres issuing from the sacral region of the medulla spinalis are *parasympathetic*; they do not join the sympathetic ganglia but pass as the *pelvic splanchnic nerves* of Gaskell to the pelvic plexuses. The *afferent* fibres are derived partly from the unipolar cells and partly from the multipolar cells of the spinal ganglia. Their peripheral processes are carried through the white rami communicantes, and after passing without interruption through one or more sympathetic ganglia end in the tissues of the viscera. The central processes of the unipolar cells enter the medulla spinalis through the posterior nerve-roots and form synapses around either somatic or sympathetic efferent neurons, thus completing reflex arcs. Some authorities believe that the cells of Dogiel in the spinal ganglia (p. 926) bring the autonomic afferent neurons into relationship with those of the somatic system, and so render possible the transference of an impulse from the former to the sensorium.

Divisions.—After emerging from the intervertebral foramen, each spinal nerve supplies a small *meningeal branch* which re-enters the vertebral canal through the intervertebral foramen and is distributed to the vertebræ and their ligaments, and the blood-vessels of the medulla spinalis and its membranes. The spinal nerve then splits into a *posterior* and an *anterior* division, each receiving fibres from both nerve-roots.

THE POSTERIOR DIVISIONS OF THE SPINAL NERVES

The **posterior divisions** of the spinal nerves are as a rule smaller than the anterior. They are directed backwards, and, with the exceptions of those of the first cervical, the fourth and fifth sacral, and the coccygeal, divide into medial and lateral branches for the supply of the muscles and skin (fig. 907) of the posterior part of the trunk.

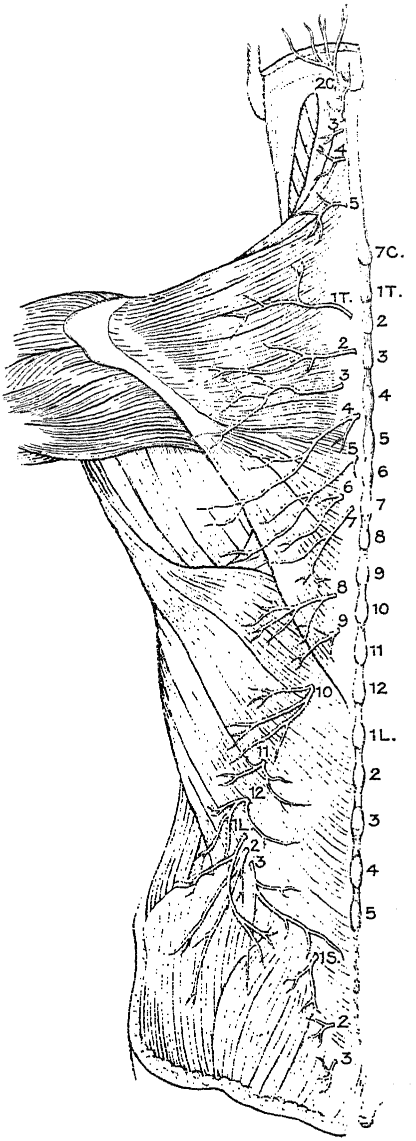
The Posterior Divisions of the Cervical Nerves

The **posterior division of the first cervical or suboccipital nerve** is larger than the anterior division, and emerges above the posterior arch of the atlas and beneath the vertebral artery. It enters the suboccipital triangle and supplies the muscles which bound this triangle, viz. the Rectus capitis posterior major, and the Obliqui superior et inferior; it gives branches also to the Rectus capitis posterior minor and the Semispinalis capitis. A filament from the branch to the Obliquus inferior joins the posterior division of the second cervical nerve.

The nerve occasionally gives off a cutaneous branch which accompanies the occipital artery to the scalp, and communicates with the greater and lesser occipital nerves.

The **posterior division of the second cervical nerve** is much larger than the anterior division, and is the greatest of all the cervical posterior divisions. It emerges between the posterior arch of the atlas and the lamina of the epistropheus, below the Obliquus inferior. It supplies a twig to this muscle, receives a communicating filament from the posterior division of the first cervical, and then divides into a large medial and a small lateral branch.

FIG. 907.—A diagram showing the distribution of the cutaneous branches of the posterior divisions of the spinal nerves.



The *medial* branch, called from its size and distribution, the *greater occipital nerve*, ascends obliquely between the Obliquus inferior and the Semispinalis capitis, and pierces the latter muscle and the Trapezius near their attachments to the occipital bone (fig. 907). It is then joined by a filament from the medial branch of the posterior division of the third cervical, and, ascending on the back of the head with the occipital artery, divides into branches which communicate with the lesser occipital nerve and supply the skin of the scalp as far forward as the vertex of the skull. It gives muscular branches to the Semispinalis capitis, and occasionally a twig to the back of the auricula. The *lateral* branch supplies filaments to the Splenius, Longus capitis, and Semispinalis capitis, and is often joined by the corresponding branch of the third cervical.

The **posterior division of the third cervical nerve** is intermediate in size between those of the second and fourth. Its *medial* branch runs between the Semispinalis capitis and Semispinalis cervicis, and, piercing the Splenius and Trapezius, ends in the skin. While under the Trapezius it gives a branch called the *third occipital nerve*, which pierces the Trapezius and ends in the skin of the lower part of the back of the head (fig. 907). It lies medial to, and communicates with, the greater occipital nerve. The *lateral* branch often joins that of the second cervical.

The posterior division of the suboccipital, and the medial branches of the posterior divisions of the second and third cervical nerves are sometimes joined by communicating loops to form the *posterior cervical plexus* (Cruveilhier).

The **posterior divisions of the lower five cervical nerves** divide into medial and lateral branches. The *medial* branches of the fourth and fifth run between the Semispinalis cervicis and Semispinalis capitis, and, having reached the spinous processes of the vertebræ, pierce the Splenius and Trapezius to end in the skin (fig. 907). Sometimes the medial branch of the fifth fails to reach the skin. The medial branches of the lowest three nerves are small, and end in the Semispinalis cervicis, Semispinalis capitis, Multifidus and Interspinales. The *lateral* branches of the lower five nerves supply the Iliocostalis cervicis, Longissimus cervicis, and Longissimus capitis.

The *dental branches* supply the molar and premolar teeth, and the gum. Before the branches enter the roots of the teeth they communicate with one another and form an inferior dental plexus.

The *incisive branch* is continued onwards within the bone and supplies the canine and incisor teeth.

The *mental nerve* emerges at the mental foramen, and divides beneath the Triangularis muscle into three branches; one descends to the skin of the chin, and two ascend to the skin and mucous membrane of the lower lip; these branches communicate freely with the facial nerve.

Two small ganglia, the otic and the submaxillary, are connected with the mandibular nerve.

The **otic ganglion** (fig. 888) is a small, oval-shaped, flattened ganglion of a reddish-grey colour, situated immediately below the foramen ovale; it lies on the medial surface of the mandibular nerve, and surrounds the origin of the nerve to the Pterygoideus internus. It is in relation, *laterally*, with the trunk of the mandibular nerve at the point where the motor and sensory roots join; *medially*, with the cartilaginous part of the auditory tube; *posteriorly*, with the middle meningeal artery.

It is connected by two or three short filaments with the nerve to the Pterygoideus internus, from which it may obtain a motor root (fig. 889). It communicates with the glossopharyngeal and facial nerves, through the lesser superficial petrosal nerve continued from the tympanic plexus, and through this nerve may receive sensory fibres from the glossopharyngeal nerve and a parasympathetic root from the facial nerve; its sympathetic root is a filament from the sympathetic plexus on the middle meningeal artery.

Branches.—A twig (*sphenoidal*) ascends from the otic ganglion to the nerve of the pterygoid canal, and another connects the ganglion with the chorda tympani nerve. Two or more branches run backwards and join the roots of the auriculotemporal nerve; these branches probably carry secretory fibres from the glossopharyngeal nerve to the parotid gland. A filament is supplied to the Tensor tympani muscle, and another to the Tensor veli palatini muscle. The former passes backwards, lateral to the auditory tube; the latter arises from the ganglion, near the origin of the nerve to the Pterygoideus internus, and is directed forwards. The fibres of the nerves to the Tensor tympani and Tensor veli palatini are mainly derived from the nerve to the Pterygoideus internus.

The **submaxillary ganglion** (fig. 884) is of small size, and fusiform in shape. It is situated above the deep portion of the submaxillary gland, on the Hyoglossus, near the posterior border of the Mylohyoideus. It is suspended from the lingual nerve by an anterior and a posterior filament. Through the posterior filament it receives its parasympathetic root from the chorda tympani nerve which runs in the sheath of the lingual, and its sensory root from the lingual nerve. The ganglion receives its sympathetic root from the plexus around the external maxillary (facial) artery (fig. 890).

Five or six branches arise from the lower part of the ganglion, and supply the mucous membrane of the mouth, and the submaxillary gland and its duct. Fibres pass through the filament connecting the fore part of the ganglion to the lingual nerve, and are conveyed to the sublingual gland and the tongue.

Applied Anatomy.—Paralysis of the trigeminal nerve causes anæsthesia of the corresponding anterior half of the scalp, of the face (excepting over a small area near the angle of the mandible supplied by the cervical nerves), of the cornea and conjunctiva, and of the mucous membrane of the nose, mouth, and tongue. Taste is lost (*ageusia*) on the affected side. Paralysis and atrophy follow in the Temporalis, Masseter, and Pterygoidei, possibly also in the Tensor tympani; when the mouth is opened the mandible is thrust over towards the paralysed side. Interference with the secretion of the tears, the nasal mucus, and the saliva, causes dryness of the corresponding mucous membranes. The sense of smell is gradually lost on the affected side from the trophic changes that follow in the nasal mucous membrane. Inflammation of the eyeball, under these circumstances known as neuroparalytic ophthalmia, is not rare, and is due to the dryness and insensitiveness of the conjunctiva; it is not a 'trophic' phenomenon, but depends on the occurrence and neglect of traumatic inflammation in the anæsthetic eye.

Trigeminal nerve reflexes.—Pains referred to various branches of the trigeminal nerve are of very frequent occurrence. As a general rule the diffusion of pain over the various branches of the nerve is at first confined to one only of the main divisions, although

THE ANTERIOR DIVISIONS OF THE SPINAL NERVES

The **anterior divisions of the spinal nerves** supply the anterolateral parts of the trunk, and the limbs; they are for the most part larger than the posterior divisions. In the thoracic region they run independently of one another, but in the cervical, lumbar, and sacral regions they unite near their origins to form plexuses.

THE ANTERIOR DIVISIONS OF THE CERVICAL NERVES

The **anterior divisions of the cervical nerves,** with the exception of the first, appear between the corresponding anterior and posterior intertransverse muscles. The anterior divisions of the *upper four* nerves unite to form the *cervical plexus*; those of the *lower four*, together with the greater part of the anterior division of the first thoracic nerve, join to form the *brachial plexus*.

Each nerve receives a grey ramus communicans, the upper four from the superior cervical ganglion, the fifth and sixth from the middle cervical ganglion, and the seventh and eighth from the inferior cervical ganglion, of the sympathetic trunk.

The anterior division of the *first cervical* (*suboccipital*) *nerve* appears above the posterior arch of the atlas vertebra, and passes forwards round the lateral side of its superior articular process, medial to the vertebral artery. It supplies a branch to the Rectus lateralis, and, emerging on the medial side of that muscle, descends in front of the transverse process of the atlas and joins with the ascending branch of the second nerve.

The anterior division of the *second cervical nerve* issues between the neural arches of the atlas and epistropheus and runs forwards between the transverse processes of these two vertebræ, passing under cover of the first posterior intertransverse muscle and on the lateral side of the vertebral artery. It divides into an ascending branch which joins with the first cervical nerve, and a descending branch which unites with the ascending branch of the third cervical nerve.

The Cervical Plexus

The **cervical plexus** (fig. 908) is formed by the anterior divisions of the upper four cervical nerves; each nerve, except the first, divides into an upper and a lower branch, and these unite to form three loops. The plexus is situated opposite the upper four cervical vertebræ, in front of the Levator scapulæ and Scalenus medius, and beneath the Sternocleidomastoideus.

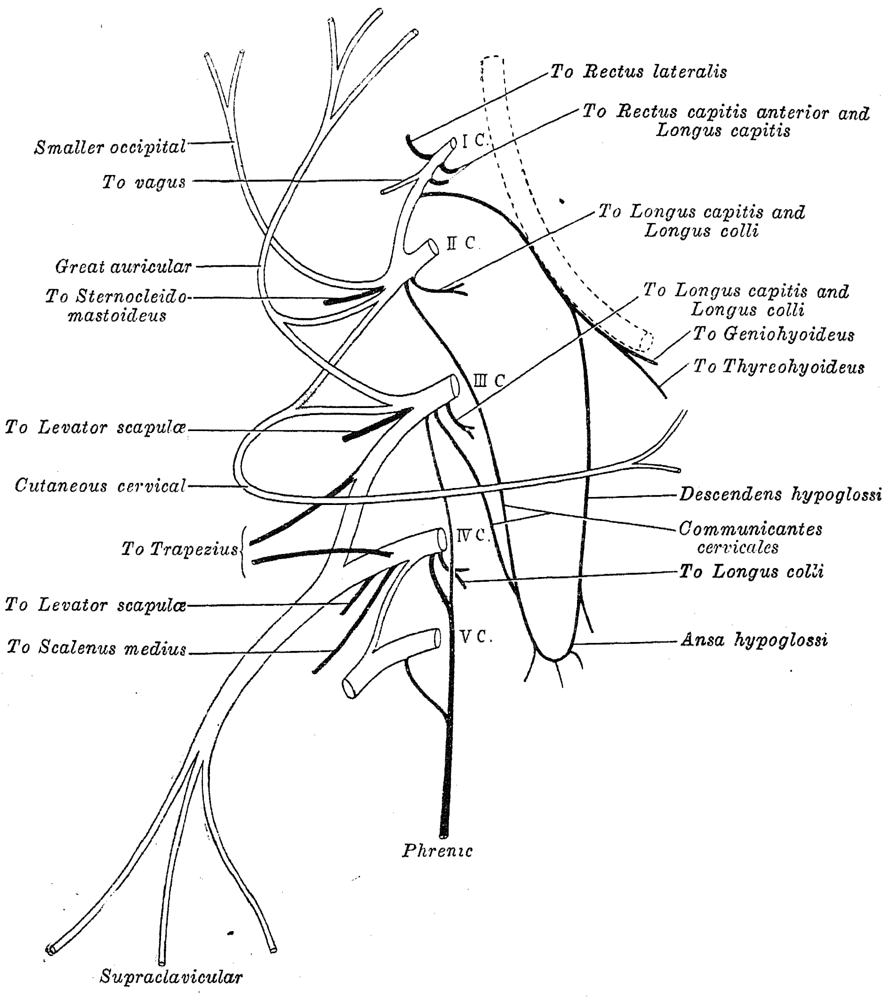
Its branches are divided into two groups, *superficial* and *deep*, and are here given in tabular form; the figures following the names indicate the spinal nerves from which the different branches take origin:

Superficial			Smaller occipital	2 C.
			Great auricular	2, 3 C.
			Cutaneous cervical	2, 3 C.
			Supraclavicular	3, 4 C.
Deep	Medial	Communicating	With hypoglossal	1, 2 C.
			,, vagus	1, 2 C.
			,, sympathetic	1, 2, 3, 4 C.
		Muscular	Rectus capitis lateralis	1 C.
			Rectus capitis anterior	1, 2 C.
			Longus capitis	1, 2, 3 C.
			Longus colli	2, 3, 4 C.
			Communicantes cervicales	2, 3 C.
			Phrenic	3, 4, 5 C.
	Lateral	Communicating with accessory		2, 3, 4 C.
		Muscular	Sternocleidomastoideus	2 C.
			Trapezius	3, 4 C.
			Levator scapulæ	3, 4 C.
			Scalenus medius	3 4 C.

The Superficial Branches of the Cervical Plexus (figs. 908, 909)

The **smaller occipital nerve** arises from the second cervical nerve, sometimes also from the third; it hooks round the accessory nerve and ascends along the posterior border of the Sternocleidomastoideus. Near the cranium it perforates the deep fascia, and is continued upwards along the side of the head behind the auricula, supplying the skin and communicating with the great auricular and greater occipital nerves, and with the posterior auricular branch of the facial nerve. The smaller occipital nerve varies in size, and is sometimes duplicated.

Fig. 908.—A plan of the cervical plexus.



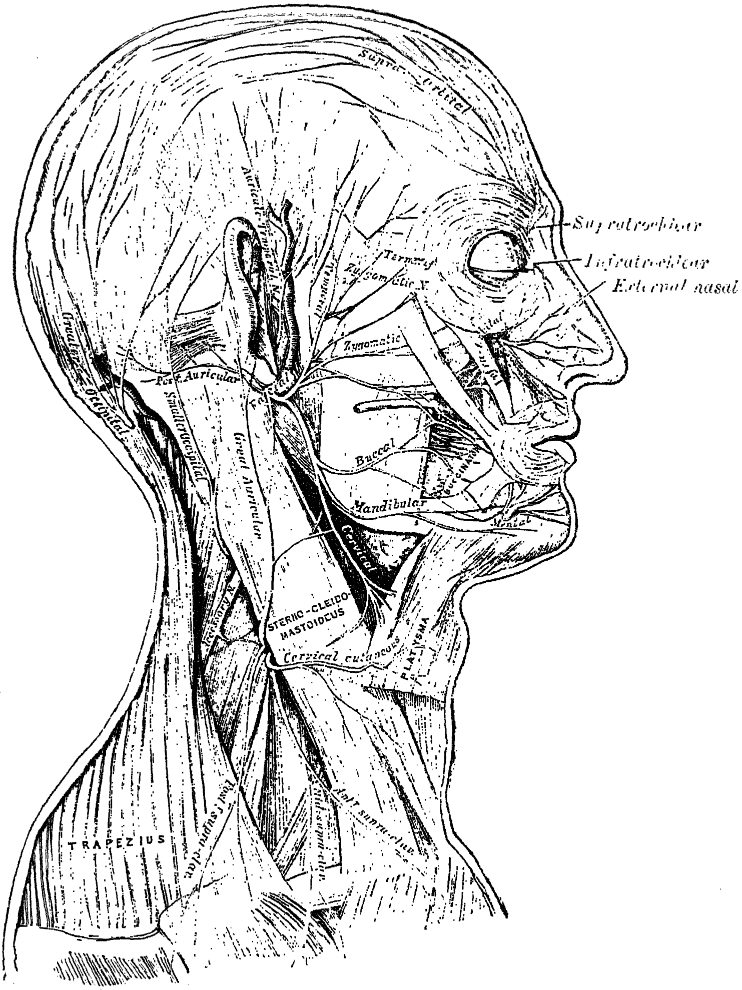
It sends off an *auricular branch* which supplies the skin of the upper third of the cranial surface of the auricula, and communicates with the mastoid branch of the great auricular nerve. The auricular branch is occasionally derived from the greater occipital nerve.

The **great auricular nerve** is the largest of the ascending branches. It arises from the second and third cervical nerves, winds round the posterior border of the Sternocleidomastoideus, and, after perforating the deep fascia ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into an anterior and a posterior branch.

The *anterior branch* is distributed to the skin of the face over the parotid gland, and communicates in the substance of the gland with the facial nerve.

The *posterior branch* supplies the skin over the mastoid process and on the back of the auricula, except at its upper part; a filament pierces the auricula to reach its lateral surface, where it is distributed to the lobule and lower part of the concha. The posterior branch communicates with the smaller occipital nerve, the auricular branch of the vagus nerve, and the posterior auricular branch of the facial nerve.

FIG. 909.—The nerves of the right side of the scalp, face, and side of neck.



The **cutaneous cervical nerve** (transverse cervical nerve) arises from the second and third cervical nerves, turns round the posterior border of the Sternocleidomastoideus about its middle, and passes obliquely forwards behind the external jugular vein to the anterior border of the muscle. It perforates the deep cervical fascia, and divides beneath the Platysma into ascending and descending branches, which are distributed to the anterolateral parts of the neck.

The *ascending branches* pass upwards to the submaxillary region, and form a plexus with the cervical branch of the facial nerve, beneath the Platysma; others pierce that muscle, and are distributed to the skin of the upper and front parts of the neck.

The *descending branches* pierce the Platysma, and are distributed to the skin of the side and front of the neck, as low as the sternum.

The **supraclavicular nerves** arise by a common trunk derived from the third and fourth cervical nerves. This trunk emerges from beneath the posterior

border of the Sternocleidomastoideus, descends under cover of the Platysma and deep cervical fascia, and subdivides into anterior, middle, and posterior branches which diverge from one another and pierce the deep fascia a little above the level of the clavicle.

The *anterior supraclavicular nerves* cross obliquely over the external jugular vein and the clavicular and sternal heads of the Sternocleidomastoideus, and supply the skin as far as the middle line. They furnish one or two filaments to the sternoclavicular joint.

The *middle supraclavicular nerves* cross the clavicle, and supply the skin over the Pectoralis major and Deltoideus, communicating with the cutaneous branches of the upper intercostal nerves.

The *posterior supraclavicular nerves* pass obliquely across the outer surface of the Trapezius and the acromion, and supply the skin of the upper and posterior parts of the shoulder.

Applied Anatomy.—Pains referred to the superficial terminal branches of the cervical plexus are not uncommon in caries of the cervical vertebræ, where pain may be felt radiating over the occipital bone, if the disease is situated high up in the vertebral column.

The Deep Branches of the Cervical Plexus. Medial Series

The **communicating branches** consist of several filaments, which pass from the loop between the first and second cervical nerves to the vagus, hypoglossal, and sympathetic. The branch to the hypoglossal ultimately leaves that nerve as a series of branches, viz. the meningeal, the descending ramus, the nerve to the Thyreohyoideus and the nerve to the Geniohyoideus (p. 925). A communicating branch also passes from the fourth to the fifth cervical nerve, while each of the first four cervical nerves receives a grey ramus communicans from the superior cervical ganglion of the sympathetic trunk.

Muscular branches supply the Rectus capitis lateralis, Rectus capitis anterior, Longus capitis, and Longus colli.

The **communicantes cervicales** (fig. 908) consist usually of two branches, one derived from the second and the other from the third cervical nerve. These branches join to form the *descendens cervicalis*, which passes downwards on the lateral side of the internal jugular vein, crosses in front of this vein a little below the middle of the neck, and forms a loop (*ansa hypoglossi*) with the descending ramus of the hypoglossal nerve (p. 925) in front of the sheath of the carotid vessels. Occasionally the loop is formed within the sheath.

The **phrenic nerve** contains motor and sensory fibres in the proportion of about two to one. It arises chiefly from the fourth cervical nerve, but receives a branch from the third and another from the fifth; the fibres from the fifth occasionally come through the nerve to the Subclavius (p. 937). It is formed at the lateral border of the Scalenus anterior, and running obliquely across the front of that muscle, descends to the root of the neck, beneath the Sternocleidomastoideus, the inferior belly of the Omohyoideus, and the transverse cervical and transverse scapular vessels. It next passes in front of the subclavian artery, between it and the subclavian vein, and, as it enters the thorax, crosses from the lateral to the medial side of the internal mammary artery. Within the thorax, it descends nearly vertically in front of the root of the lung, and then between the pericardium and the mediastinal pleura, to the Diaphragm, where it divides into branches which pierce that muscle, and are distributed to its under surface. In the thorax it is accompanied by the pericardiacophrenic branch of the internal mammary artery.

The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax.

The *right nerve* is situated more deeply, and is shorter and more vertical in direction than the left. It descends in front of the Scalenus anterior which separates it from the second part of the subclavian artery. It lies lateral to the right innominate vein and superior vena cava.

The *left nerve* is rather longer than the right, owing to the inclination of the heart to the left side, and from the Diaphragm being lower on this than on the right side. At the root of the neck it crosses the first part of the subclavian artery, and is crossed by the thoracic duct. In the superior mediastinal cavity

it lies between the left common carotid and left subclavian arteries, and crosses superficial to the vagus on the left side of the arch of the aorta.

Each nerve supplies branches to the pericardium and pleura, and at the root of the neck is joined by a filament from the sympathetic, and, occasionally, by one from the ansa hypoglossi.

From the *right nerve*, one or two filaments pass to join in a small *phrenic ganglion* with phrenic branches of the cœliac plexus; and branches from this ganglion are distributed to the falciform and coronary ligaments of the liver, the suprarenal gland, and inferior vena cava. From the *left nerve*, filaments pass to join the phrenic branches of the cœliac plexus, but without any ganglionic enlargement; and a twig is distributed to the left suprarenal gland.

Applied Anatomy.—In addition to its supply from the phrenics, the Diaphragm receives both motor and sensory nerve-fibres from the lower seven intercostal nerves at its rim. This double sensory innervation explains the varied distribution of the referred pains that may be felt in different cases of infection or inflammation of the Diaphragm, such as may occur in pleurisy or pneumonia affecting its upper surface, on the one hand, or in peritonitis attacking its lower surface on the other. For example, if it is the more central part of the Diaphragm that becomes inflamed in a case of acute peritonitis, the patient may complain of pain and tenderness in the area of distribution of the cutaneous branches of the fourth and fifth cervical nerves, with the result that disease of the shoulder-joint or supraclavicular region is erroneously suspected, and the peritonitis is missed. Contrariwise, if the periphery of the Diaphragm chances to become infected in a patient with acute pleurisy or pneumonia, he may complain of acute pain and tenderness in the area of distribution of the cutaneous branches of the lower intercostal nerves, and may also exhibit rigidity of the underlying abdominal muscles, with the result that an acute intra-abdominal infection is erroneously diagnosed and a laparotomy is performed for the relief of a supposed appendicitis, cholecystitis, or localised peritonitis.

The Deep Branches of the Cervical Plexus. Lateral Series

Communicating branches.—The lateral series of deep branches of the cervical plexus communicates with the accessory nerve, in the substance of the Sternocleidomastoideus, in the posterior triangle, and beneath the Trapezius.

Muscular branches are distributed to the Sternocleidomastoideus, Trapezius, Levator scapulæ, and Scalenus medius.

The branch for the Sternocleidomastoideus is derived from the second cervical nerve; the Trapezius and Levator scapulæ receive branches from the third and fourth cervical nerves. The Scalenus medius receives twigs either from the third or fourth cervical nerves, or occasionally from both.

The Brachial Plexus

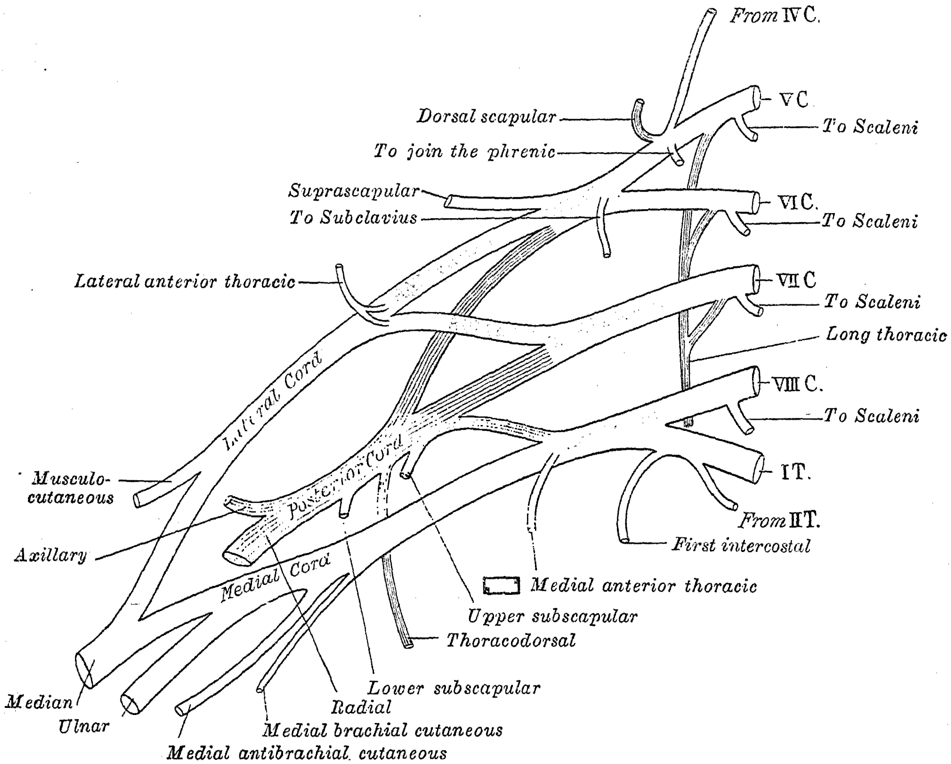
The **brachial plexus** (fig. 910) is formed by the union of the anterior divisions of the lower four cervical nerves and the greater part of the anterior division of the first thoracic nerve; the fourth cervical nerve usually gives a branch to the fifth cervical, and the first thoracic nerve frequently receives one from the second thoracic. The plexus extends from the lower part of the side of the neck to the axilla. The nerves which form it are nearly equal in size, but their mode of communication is subject to some variation. The following is, however, the most constant arrangement. The fifth and sixth cervical nerves unite at the lateral border of the Scalenus medius to form a trunk. The eighth cervical and first thoracic nerves unite behind the Scalenus anterior to form a trunk, while the seventh cervical nerve runs alone. Three trunks—upper, middle, and lower—are thus formed, and, as they pass beneath the clavicle, each splits into an *anterior* and a *posterior* division.* The anterior divisions of the upper and middle trunks unite to form a cord, which is situated on the lateral side of the second part of the axillary artery, and is called the *lateral cord or fasciculus* of the plexus. The anterior division of the lower trunk passes down on the medial side of the second part of the axillary artery, and forms the *medial cord or fasciculus* of the brachial plexus; this cord frequently receives fibres from the seventh cervical nerve. The posterior

* The posterior division of the lower trunk is very much smaller than the others, and is frequently derived entirely from the eighth cervical nerve.

divisions of all three trunks unite to form the *posterior cord or fasciculus* of the plexus, which is situated behind the second portion of the axillary artery.

Relations.—*In the neck*, the brachial plexus lies in the posterior triangle, being covered by the skin, Platysma, and deep fascia; it is crossed by the supraclavicular nerves, the nerve to the Subclavius, the inferior belly of the Omohyoideus, the external jugular vein, and the transverse cervical artery. It emerges between the Scalenus anterior and Scalenus medius; its upper part lies above the third part of the subclavian artery, while the trunk formed by the union of the eighth cervical and first thoracic nerves is placed behind the artery; the plexus next passes behind the clavicle, the Subclavius, and the

Fig. 910.—A plan of the brachial plexus.



transverse scapular vessels, and lies upon the first digitation of the Serratus anterior, and the Subscapularis. *In the axilla* the lateral and posterior cords of the plexus are on the lateral side of the first part of the axillary artery, and the medial cord behind it. The cords surround the second part of the axillary artery on three sides, the medial cord lying on the medial side, the posterior cord behind, and the lateral cord on the lateral side of the artery. In the lower part of the axilla the cords split into the nerves for the upper limb.

Close to their exit from the intervertebral foramina the fifth and sixth cervical nerves each receive a grey ramus communicans from the middle cervical ganglion, and the seventh and eighth cervical similar rami from the inferior cervical ganglion, of the sympathetic trunk. The first thoracic nerve receives a grey ramus from, and contributes a white ramus to, the first thoracic ganglion of the sympathetic trunk.

The **branches of the brachial plexus.**—The branches of the brachial plexus are usually subdivided into two groups, viz. those arising above the clavicle (*supraclavicular*) and those below that bone (*infraclavicular*).

The Supraclavicular Branches

The supraclavicular branches may be grouped as follows: (*a*) those arising from the anterior divisions of the cervical nerves, and (*b*) those from the trunks of the plexus.

From the anterior divisions of the cervical nerves.	1. To Scaleni and Longus colli .	5, 6, 7, 8 C.
	2. To join phrenic nerve . .	5 C.
	3. Dorsal scapular nerve . .	5 C.
	4. Long thoracic nerve . .	5, 6, 7 C.
From the trunks of the plexus.	1. Nerve to Subclavius . .	5, 6 C.
	2. Suprascapular nerve . .	5, 6 C.

The branches for the Scaleni and Longus colli arise from the lower four cervical nerves close to their points of exit from the intervertebral foramina.

On the Scalenus anterior the phrenic nerve is joined by a branch from the fifth cervical nerve.

The **dorsal scapular nerve** arises from the fifth cervical nerve, pierces the Scalenus medius, passes beneath the Levator scapulæ, to which it occasionally gives a twig, and runs in company with the descending branch of the transverse cervical artery on the anterior surfaces of the Rhomboidei; it ends by supplying these muscles.

The **long thoracic nerve** (nerve of Bell) (fig. 915) supplies the Serratus anterior. It usually arises by three roots from the fifth, sixth, and seventh cervical nerves, but the root from the seventh nerve may be absent. The roots from the fifth and sixth nerves pierce the Scalenus medius, while that from the seventh passes lateralwards in front of the muscle. The nerve descends behind the brachial plexus and the first part of the axillary vessels, resting on the outer surface of the Serratus anterior. It is continued down to the lower border of that muscle, supplying, in its course, filaments to each of the digitations of the muscle.

The **nerve to the subclavius** is a small nerve which arises from the point of junction of the fifth and sixth cervical nerves; it descends to the muscle in front of the third part of the subclavian artery and the lower trunk of the plexus, and is usually connected by a filament with the phrenic nerve.

The **suprascapular nerve** (fig. 916) is a large nerve which arises from the trunk formed by the union of the fifth and sixth cervical nerves. It runs lateralwards beneath the Trapezius and the Omohyoideus, and enters the supraspinatous fossa through the suprascapular notch, below the superior transverse scapular ligament; it then passes beneath the Supraspinatus, and curves round the lateral border of the spine of the scapula to the infraspinatous fossa in company with the transverse scapular artery. In the supraspinatous fossa it gives two branches to the Supraspinatus muscle, and articular filaments to the shoulder-joint and acromioclavicular joint; and in the infraspinatous fossa it gives two branches to the Infraspinatus muscle, besides some filaments to the shoulder-joint and scapula.

The Infraclavicular Branches

The infraclavicular branches are derived from the three cords of the brachial plexus, but their fibres may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

Lateral cord .	Lateral anterior thoracic . .	5, 6, 7 C.
	Musculocutaneous . . .	5, 6, 7 C.
	Lateral head of median . .	6, 7 C.
	Ulnar*	7, 8, C., 1 T.
Medial cord .	Medial anterior thoracic .	8 C., 1 T.
	Medial antibrachial cutaneous .	8 C., 1 T.
	Medial brachial cutaneous . .	8 C., 1 T.
	Medial head of median . .	8 C., 1 T.
Posterior cord .	Upper subscapular . . .	5, 6 C.
	Lower subscapular . . .	5, 6 C.
	Axillary	5, 6 C.
	Thoracodorsal	6, 7, 8 C.
	Radial	5, 6, 7, 8 C., 1 T.

* See footnote on p. 942.

The **anterior thoracic nerves** (fig. 915) supply the Pectoralis major and Pectoralis minor.

The *lateral anterior thoracic nerve*, the larger of the two, may arise by two roots from the anterior divisions of the upper and middle trunks, or by a single root from the point where these divisions unite to form the lateral cord of the plexus; it receives its fibres from the fifth, sixth, and seventh cervical nerves. It crosses the axillary artery and vein, pierces the coracoclavicular fascia, and is distributed to the deep surface of the Pectoralis major. It sends a filament to join the medial anterior thoracic nerve and form with it a loop in front of the first part of the axillary artery; through this loop the lateral anterior thoracic nerve distributes some fibres to the Pectoralis minor.

The *medial anterior thoracic nerve* receives its fibres from the eighth cervical and first thoracic nerves, and arises from the medial cord of the plexus while that cord is still on the lateral side of the axillary artery. It passes behind the first part of the axillary artery, curves forwards between the axillary artery and vein, and unites in front of the artery with a filament from the lateral anterior thoracic nerve. It then enters the deep surface of the Pectoralis minor and supplies that muscle. Two or three branches pierce the Pectoralis minor, and others may pass round its inferior border, and end in the Pectoralis major.

The **subscapular nerves,** two in number, spring from the posterior cord of the plexus, and through it from the fifth and sixth cervical nerves.

The *upper subscapular nerve*, the smaller, enters the upper part of the Subscapularis, and is frequently represented by two branches.

The *lower subscapular nerve* supplies the lower part of the Subscapularis, and ends in the Teres major; the latter muscle is sometimes supplied by a separate branch.

The **thoracodorsal nerve** (long subscapular nerve), a branch of the posterior cord of the plexus, derives its fibres from the sixth, seventh and eighth cervical nerves; it accompanies the subscapular artery, along the posterior wall of the axilla and supplies the Latissimus dorsi, in which it may be traced as far as the lower border of the muscle.

The **axillary nerve** (circumflex nerve) (fig. 916) arises from the posterior cord of the brachial plexus, its fibres being derived from the fifth and sixth cervical nerves. It lies at first behind the axillary artery and in front of the Subscapularis, and at the lower border of that muscle winds backwards in close relation to the lowest part of the articular capsule of the shoulder-joint, and, in company with the posterior humeral circumflex artery, through a quadrilateral space bounded above by the Subscapularis in front and the Teres minor behind, below by the Teres major, medially by the long head of the Triceps brachii and laterally by the surgical neck of the humerus. It ends by dividing into an anterior and a posterior branch.

The *anterior branch*, accompanied by the posterior humeral circumflex vessels, winds round the surgical neck of the humerus, beneath the Deltoideus, as far as the anterior border of the muscle, supplying it, and giving a few small cutaneous branches, which pierce the muscle and ramify in the skin covering its lower part.

The *posterior branch* supplies the Teres minor and the posterior part of the Deltoideus; upon the branch to the Teres minor an oval enlargement (pseudoganglion) usually exists. The posterior branch then pierces the deep fascia and is continued as the *lateral brachial cutaneous nerve*, which sweeps round the posterior border of the Deltoideus and supplies the skin over the lower two-thirds of the posterior part of this muscle, as well as that covering the long head of the Triceps brachii (figs. 911, 913).

The trunk of the axillary nerve gives an articular filament which enters the shoulder-joint below the Subscapularis.

The **musculocutaneous nerve** (fig. 915) arises from the lateral cord of the brachial plexus, opposite the lower border of the Pectoralis minor, its fibres being derived from the fifth, sixth, and seventh cervical nerves. It pierces the Coracobrachialis and passes obliquely between the Biceps brachii and the Brachialis to the lateral side of the arm; a little below the elbow it pierces the deep fascia lateral to the tendon of the Biceps brachii and is continued into the forearm as the *lateral antibrachial cutaneous nerve*. In its course through the arm it supplies the Coracobrachialis, Biceps brachii,

and the greater part of the Brachialis. The branch to the Coracobrachialis leaves the musculocutaneous nerve before that nerve enters the muscle; it receives its fibres from the seventh cervical nerve, and in some instances arises

FIG. 911.—The cutaneous nerves of the right upper extremity. Anterior aspect.

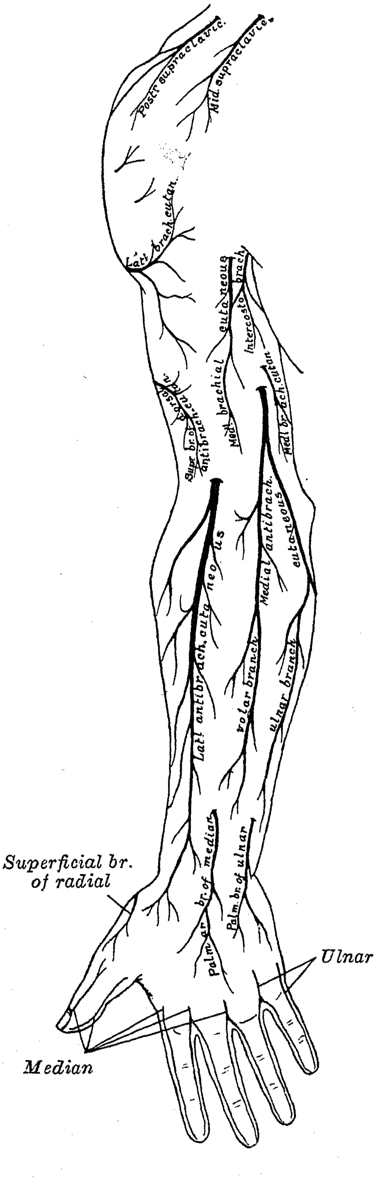
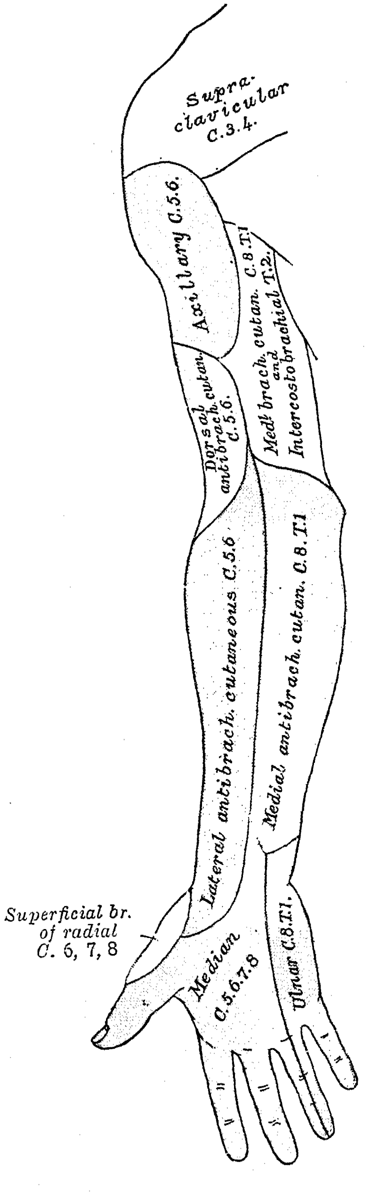


FIG. 912.—A diagram showing the segmental distribution of the cutaneous nerves of the right upper extremity. Anterior aspect.



directly from the lateral cord of the brachial plexus. The branches to the Biceps brachii and Brachialis leave the musculocutaneous nerve after it has pierced the Coracobrachialis; that supplying the Brachialis gives a filament to the elbow-joint. The nerve also sends a small branch to the humerus; this branch enters the bone with the nutrient artery.

The *lateral antibrachial cutaneous nerve* (fig. 911) passes behind the cephalic vein, and descends along the radial border of the forearm to the wrist. It

supplies the skin over the lateral half of the volar surface of the forearm and distributes branches which turn round the radial border of the forearm to communicate with the dorsal antibrachial cutaneous nerve and the superficial branch of the radial nerve. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the dorsal surface of the carpus. The nerve then passes downwards to the ball of the thumb, where it ends in cutaneous filaments. It communicates with the superficial branch of the radial nerve, and with the palmar cutaneous branch of the median nerve.

The musculocutaneous nerve presents frequent irregularities. It may pass under the Coracobrachialis or through the Biceps brachii. It may adhere for some distance to the median nerve and then pass beneath the Biceps brachii instead of through the Coracobrachialis. Some of the fibres of the median nerve may run for some distance in the musculocutaneous nerve and then leave the latter to join their proper trunk; less frequently the reverse is the case, and the median nerve sends a branch to join the musculocutaneous nerve. Occasionally it gives a filament to the Pronator teres. It supplies the dorsal surface of the thumb when the superficial branch of the radial nerve is absent.

The **medial antibrachial cutaneous nerve** (internal cutaneous nerve) (fig. 915) arises from the medial cord of the brachial plexus. It derives its fibres from the eighth cervical and first thoracic nerves, and at its commencement is placed between the axillary artery and vein. Near the axilla it supplies a filament which pierces the fascia and is distributed to the skin covering the Biceps brachii, almost as far as the elbow. The nerve then runs down the arm on the medial side of the brachial artery, pierces the deep fascia with the basilic vein, about the middle of the arm, and divides into a volar and an ulnar branch.

The *volar branch*, the larger, passes usually in front of, but occasionally behind, the median cubital vein (median basilic vein). It then descends on the front of the medial side of the forearm, distributing filaments to the skin as far as the wrist, and communicating with the palmar cutaneous branch of the ulnar nerve (fig. 911).

The *ulnar branch* passes obliquely downwards on the medial side of the basilic vein, in front of the medial epicondyle of the humerus, winds round to the back of the forearm, and descends on its medial side as far as the wrist, distributing filaments to the skin. It communicates with the medial brachial cutaneous nerve, the dorsal antibrachial cutaneous branch of the radial nerve, and the dorsal branch of the ulnar nerve (fig. 913).

The **medial brachial cutaneous nerve** (lesser internal cutaneous nerve, or nerve of Wrisberg) is distributed to the skin on the medial side of the arm (fig. 911). It is the smallest branch of the brachial plexus, and, arising from the medial cord, receives its fibres from the eighth cervical and first thoracic nerves. It passes through the axilla and crosses in front of, or behind, the axillary vein. It then runs on the medial side of this vein, and communicates with the intercostobrachial nerve. It descends along the medial side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the skin of the dorsal surface of the lower one-third of the arm, extending as far as the elbow, where some filaments are lost in the skin in front of the medial epicondyle, and others over the olecranon. It communicates with the ulnar branch of the medial antibrachial cutaneous nerve.

In some cases the medial brachial cutaneous and intercostobrachial nerves are connected by two or three filaments, which form a plexus in the axilla. In other cases the intercostobrachial nerve is large and may be reinforced by a part of the lateral cutaneous branch of the third intercostal nerve; it then takes the place of the medial brachial cutaneous nerve, receiving from the brachial plexus a communicating filament which represents the latter nerve; in a few cases this filament is wanting.

The **median nerve** (fig. 915) arises by two roots, one from the lateral and the other from the medial cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front or on the lateral side of that vessel. Its fibres are derived from the sixth, seventh, and eighth cervical and first thoracic nerves. As the median nerve descends through the arm, it lies at first lateral to the brachial artery; about the level of the insertion of

the Coracobrachialis it crosses in front of, occasionally behind, the artery, and lies medial to it at the bend of the elbow, where it is situated behind the lacertus fibrosus (bicipital fascia), and is separated from the elbow-joint by the

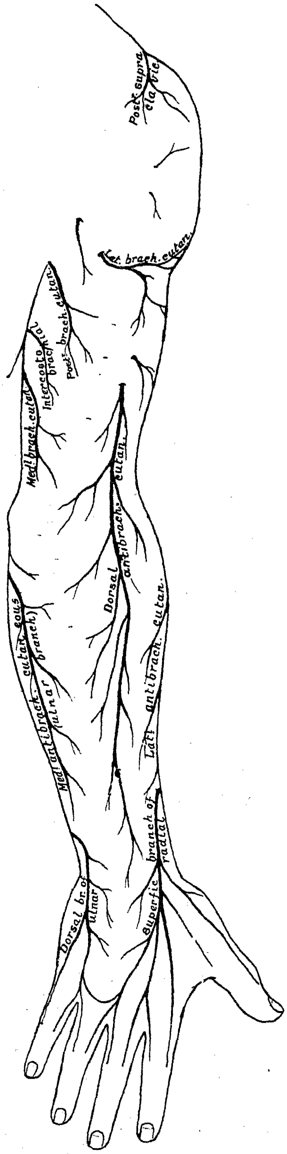


FIG. 913.—The cutaneous nerves of the right upper extremity. Posterior aspect.

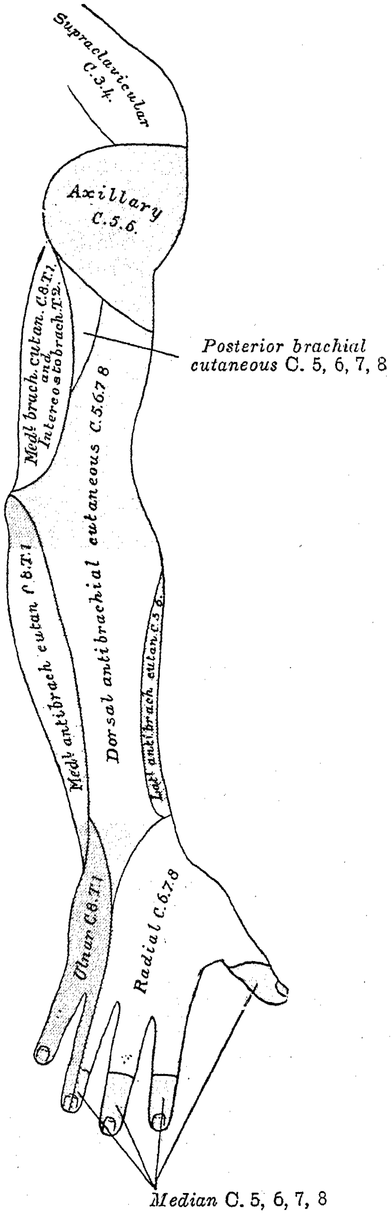


FIG. 914.—A diagram showing the segmental distribution of the cutaneous nerves of the right upper extremity. Posterior aspect.

Brachialis. It enters the forearm between the two heads of the Pronator teres and then crosses the ulnar artery, but is separated from this vessel by the deep head of the Pronator teres. It descends beneath, and adheres to, the Flexor digitorum sublimis, lying on the Flexor digitorum profundus, to within 5 cm. of the transverse carpal ligament; here it becomes more superficial, and is situated between the tendons of the Flexor digitorum sublimis and Flexor

carpi radialis. In this situation it lies beneath, and rather to the lateral side of, the tendon of the Palmaris longus, and is covered by the skin and fascia. It then passes behind the transverse carpal ligament into the palm of the hand. In its course through the forearm it is accompanied by the median artery, a branch of the volar interosseous artery.

Branches.—With the exception of the nerve to the Pronator teres, which derives its fibres from the sixth cervical nerve, and usually arises above the elbow-joint, the median nerve gives no branches in the arm. As it passes in front of the elbow, it supplies one or two twigs to the joint.

In the forearm its branches are: muscular, volar interosseous, and palmar.

The *muscular branches* are derived from the nerve near the elbow and supply all the superficial muscles on the front of the forearm, except the Flexor carpi ulnaris.

The *volar interosseous nerve* (anterior interosseous nerve) accompanies the volar interosseous artery along the front of the antibrachial interosseous membrane, in the interval between the Flexor pollicis longus and Flexor digitorum profundus, supplying the whole of the former and the lateral half of the latter muscle; it sends branches into the deep surface of the Pronator quadratus, and ends in the wrist-joint.

The *palmar branch* of the median nerve arises at the lower part of the forearm. It pierces the volar carpal ligament, and divides into a lateral and a medial branch; the lateral branch supplies the skin over the ball of the thumb, and communicates with the volar branch of the lateral antibrachial cutaneous nerve; the medial branch supplies the skin of the palm, and communicates with the palmar cutaneous branch of the ulnar nerve.

In the palm of the hand the median nerve is covered by the skin, the palmar aponeurosis and the superficial volar arch, and rests on the tendons of the flexor muscles. Immediately after emerging from under the transverse carpal ligament it becomes enlarged and flattened, and splits into a lateral and a medial portion. The *lateral* portion of the nerve supplies a short, stout branch to the following muscles of the ball of the thumb, viz. the Abductor brevis, the Opponens, and the superficial head of the Flexor brevis, and then divides into three *proper volar digital nerves*; two of these supply the sides of the thumb, while the third gives a twig to the first Lumbricalis and is distributed to the radial side of the index finger. The *medial* portion of the nerve divides into two *common volar digital nerves*. The first of these gives a twig to the second Lumbricalis and runs towards the cleft between the index and middle fingers, where it divides into two proper digital nerves for the adjoining sides of these digits. The second runs towards the cleft between the middle and ring fingers, and splits into two proper digital nerves for the adjoining sides of these digits; it receives a branch from the ulnar nerve, and sometimes sends a twig to the third Lumbricalis.

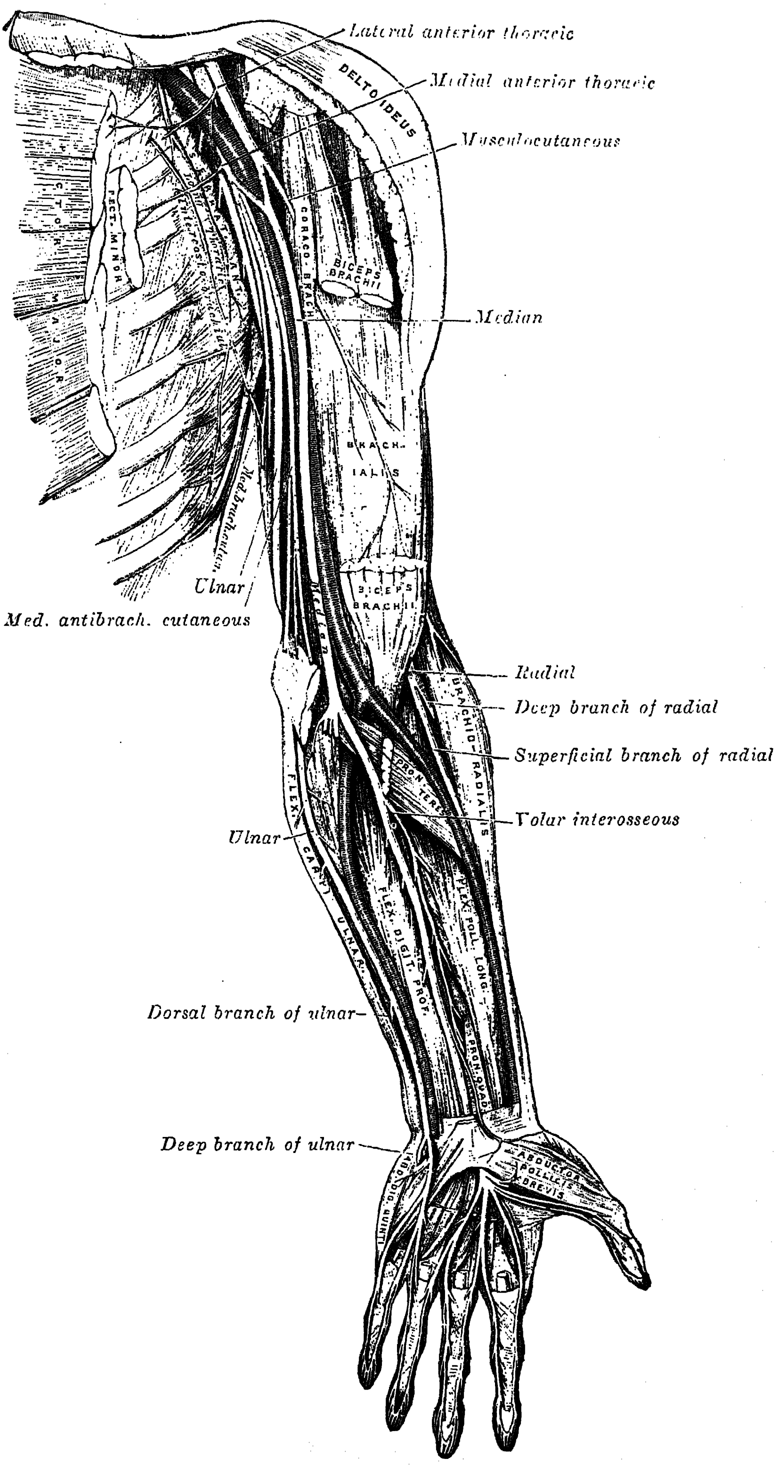
Opposite the base of the first phalanx, each proper digital nerve gives off a dorsal branch which joins the dorsal digital nerve from the superficial branch of the radial nerve, and supplies the skin on the dorsal surface of the last phalanx. At the end of the digit, each proper digital nerve divides into two branches; one supplies the pulp of the finger, the other ramifies around and beneath the nail. On the fingers the proper digital nerves are superficial to the corresponding arteries.

The **ulnar nerve** (fig. 915) arises from the medial cord of the brachial plexus, and derives its fibres from the seventh and eighth cervical and first thoracic nerves.* It lies medial to the axillary artery, and to the brachial artery as far as the middle of the arm. Here it pierces the medial intermuscular septum, and descends in front of the medial head of the Triceps brachii, to the groove between the medial epicondyle and the olecranon, accompanied by the superior ulnar collateral artery. At the elbow, it lies in the sulcus nervi ulnaris on the back of the medial epicondyle, and enters the forearm between the two

* Wilfred Harris (*Journal of Anatomy*, vol. xxxviii.) found a branch running from the seventh cervical nerve to the ulnar nerve in 86 per cent. of subjects, and believed, on clinical grounds, that the fibres of this branch were mainly motor to the Flexor carpi ulnaris.

E. A. Linell (*Journal of Anatomy*, vol. lv.) found a considerable bundle of seventh cervical nerve-fibres running from the lateral head of the median nerve to the ulnar nerve in 57 per cent. of subjects.

FIG. 915.—The nerves of the left upper extremity.



heads of the Flexor carpi ulnaris. It descends along the medial side of the forearm, lying upon the Flexor digitorum profundus ; its upper half is covered by the Flexor carpi ulnaris ; its lower half lies on the lateral side of this muscle, and is covered by the skin and fascia. In the upper one-third of the forearm, the ulnar nerve is separated from the ulnar artery by a considerable interval, but in the rest of its extent it lies close to the medial side of the artery. About 5 cm. above the wrist it divides into a dorsal and a volar branch.

The branches of the ulnar nerve are : articular to the elbow-joint, muscular, palmar cutaneous, dorsal, and volar.

The *articular branches* to the elbow-joint are several small filaments which arise from the nerve as it lies between the medial epicondyle and olecranon.

The *muscular branches,* two in number, arise near the elbow ; one supplies the Flexor carpi ulnaris ; the other, the medial half of the Flexor digitorum profundus.

The *palmar cutaneous branch* arises about the middle of the forearm, and descends on the ulnar artery, giving some filaments to the vessel. It perforates the volar carpal ligament and ends in the skin of the palm, communicating with the palmar branch of the median nerve.

The *dorsal branch* arises about 5 cm. above the wrist ; it passes backwards beneath the Flexor carpi ulnaris, perforates the deep fascia, and, running along the medial side of the back of the wrist and hand, divides into two dorsal digital branches : one supplies the medial side of the little finger ; the other, the adjacent sides of the little and ring fingers. It also sends a twig to join that given by the superficial branch of the radial nerve for the adjoining sides of the middle and ring fingers, and assists in supplying them. A branch is distributed to the metacarpal region of the hand, communicating with a twig of the superficial branch of the radial nerve (fig. 913). On the little finger the dorsal digital branches extend only as far as the base of the terminal phalanx, and on the ring finger as far as the base of the second phalanx ; the more distal parts of these digits are supplied by dorsal branches derived from the proper volar digital branches of the ulnar nerve.

The *volar branch* crosses the transverse carpal ligament on the lateral side of the pisiform bone, medial to and a little behind the ulnar artery. It ends by dividing into a superficial and a deep branch. The *superficial branch* supplies the Palmaris brevis and the skin on the medial side of the hand, and divides into a proper volar digital branch for the medial side of the little finger, and a common volar digital branch which sends a twig to join the median nerve and then divides into two proper digital nerves for the adjoining sides of the little and ring fingers (fig. 911). The proper digital branches are distributed to the fingers in the same manner as those of the median nerve. The *deep branch,* accompanied by the deep volar branch of the ulnar artery, passes between the Abductor digiti quinti and Flexor digiti quinti brevis ; it then perforates the Opponens digiti quinti and follows the course of the deep volar arch beneath the flexor tendons. At its origin it supplies the three short muscles of the little finger. As it crosses the hand, it gives branches to all the Interossei and to the third and fourth Lumbricales ; it ends by supplying the Adductor pollicis and the deep portion of the Flexor pollicis brevis. It also sends articular filaments to the wrist-joint.

It has been pointed out that the medial part of the Flexor digitorum profundus is supplied by the ulnar nerve ; the third and fourth Lumbricales, which are connected with the tendons of this part of the muscle, are supplied by the same nerve. In like manner the lateral part of the Flexor digitorum profundus and the first and second Lumbricales are supplied by the median nerve. The third Lumbricalis frequently receives an additional twig from the median nerve.

The **radial nerve** (musculospiral nerve) (fig. 916), the largest branch of the brachial plexus, derives its fibres from the fifth, sixth, seventh, and eighth cervical and first thoracic nerves. It descends behind the third part of the axillary artery and the upper part of the brachial artery and in front of the tendons of the Latissimus dorsi and Teres major. Accompanied by the arteria profunda brachii it inclines backwards between the long and medial heads of the Triceps brachii, and passes obliquely across the back of the humerus in the sulcus nervi radialis, and under cover of the lateral head of the Triceps

brachii. On reaching the lateral side of the humerus it pierces the lateral intermuscular septum, and passes between the Brachialis and Brachioradialis to the front of the lateral epicondyle, where it divides into a superficial and a deep branch.

The branches of the radial nerve are: muscular, cutaneous, superficial, and deep.

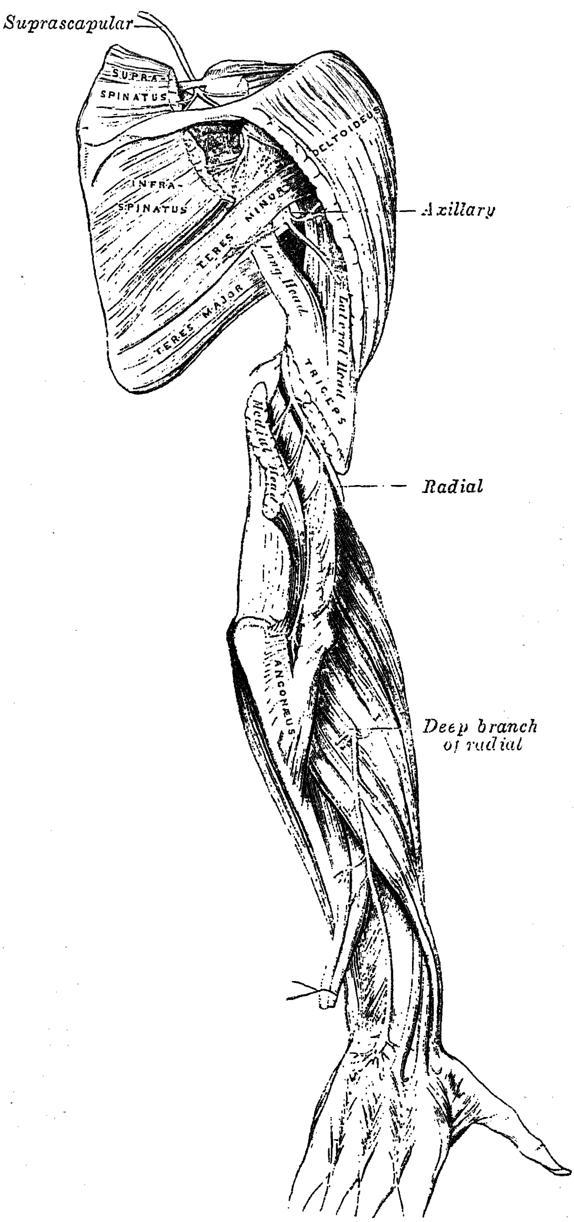
The *muscular branches* supply the Triceps brachii, Anconæus, Brachioradialis, Extensor carpi radialis longus, and Brachialis, and are grouped as medial, posterior, and lateral.

The medial muscular branches supply the medial and long heads of the Triceps brachii; that to the medial head is a long, slender filament, which lies close to the ulnar nerve as far as the lower one-third of the arm, and is therefore frequently spoken of as the *ulnar collateral nerve.*

The posterior muscular branch, of large size, arises from the nerve as it lies in the sulcus nervi radialis. It divides into filaments which supply the medial and lateral heads of the Triceps brachii and the Anconæus. The branch for the latter muscle is a long nerve which descends in the substance of the medial head of the Triceps brachii, and gives numerous branches to it. It is accompanied by the middle collateral branch of the arteria profunda brachii, and crosses the back of the elbow-joint to end in the Anconæus.

The lateral muscular branches supply the Brachioradialis, Extensor carpi radialis longus, and the lateral part of the Brachialis.

FIG. 916.—The right suprascapular, axillary, and radial nerves.



The *cutaneous branches* are two, the posterior brachial cutaneous and the dorsal antibrachial cutaneous.

The *posterior brachial cutaneous nerve* (internal cutaneous branch of the musculospiral nerve), of small size, arises in the axilla. It runs to the medial side of the arm and supplies the skin on its dorsal surface nearly as far as the olecranon. It crosses posterior to, and communicates with, the intercostobrachial nerve.

The *dorsal antibrachial cutaneous nerve* (external cutaneous branch of the

musculospiral nerve) consists of an upper and a lower branch, which perforate the lateral head of the Triceps brachii just below the insertion of the Deltoideus. The *upper* and smaller branch passes to the front of the elbow, lying close to the cephalic vein, and supplies the skin of the lateral part of the lower half of the arm (fig. 911). The *lower* branch descends along the lateral side of the arm, and then along the back of the forearm to the wrist, supplying the skin in its course, and joining, near its termination, with dorsal branches of the lateral antibrachial cutaneous nerve (fig. 913).

The **superficial branch of the radial nerve** (radial nerve) passes along the front of the lateral side of the upper two-thirds of the forearm, and ends on the back of the hand. It lies at first upon the Supinator, lateral to the radial artery, and behind the Brachioradialis. In the middle one-third of the forearm, it lies behind the latter muscle, close to the lateral side of the artery. It quits the artery about 7 cm. above the wrist, passes beneath the tendon of the Brachioradialis, and, piercing the deep fascia, divides into a lateral and a medial branch (fig. 913). The *lateral branch*, the smaller, supplies the skin of the radial side and ball of the thumb, joining with branches of the lateral antibrachial cutaneous nerve. The *medial branch* communicates, above the wrist, with dorsal branches of the lateral antibrachial cutaneous nerve, and, on the back of the hand, with the dorsal branch of the ulnar nerve. It then divides into four digital nerves, which are distributed as follows: the first supplies the medial side of the thumb; the second, the lateral side of the index finger; the third, the adjoining sides of the index and middle fingers; the fourth communicates with a filament from the dorsal branch of the ulnar nerve, and supplies the adjoining sides of the middle and ring fingers.*

The **deep branch of the radial nerve** (posterior interosseous nerve) winds to the back of the forearm round the lateral side of the radius between the two planes of fibres of the Supinator. Before reaching the back of the limb it gives a branch to the Extensor carpi radialis brevis, and another to the Supinator, and as it traverses this latter muscle it supplies additional branches to it. As it escapes from the Supinator on the back of the forearm it gives three short branches to the Extensor digitorum communis, Extensor digiti quinti proprius and Extensor carpi ulnaris, and two long branches—a medial to the Extensor pollicis longus and the Extensor indicis proprius, and a lateral which supplies the Abductor pollicis longus and ends in the Extensor pollicis brevis. The nerve, now diminished to a fine thread, descends, as the *dorsal interosseous nerve*, on the antibrachial interosseous membrane, in front of the Extensor pollicis longus, to the back of the carpus, where it presents a gangliform enlargement from which filaments are distributed to the ligaments and articulations of the carpus.

Applied Anatomy.—The brachial plexus may be injured by falls from a height on to the side of the head and shoulder, whereby the nerves of the plexus are violently stretched; the fifth cervical nerve sustains the greatest amount of injury, and the subsequent paralysis may be confined to the muscles supplied by this nerve, viz. the Deltoideus, Biceps brachii, Brachialis, and Brachioradialis, with sometimes the Supraspinatus, Infraspinatus and Supinator. The position of the limb, under such conditions, is characteristic: the arm hangs by the side and is rotated inwards; the forearm is extended and pronated. The arm cannot be raised from the side; all power of flexion of the elbow is lost, as is also supination of the forearm. This is known as Erb's paralysis, and a very similar condition is occasionally met with in new-born children, either from injury to the fifth nerve from the pressure of forceps used in effecting delivery, or from traction of the head in breech presentations. A second variety of partial palsy of the brachial plexus is known as Klumpke's paralysis. In this it is the eighth cervical and first thoracic nerves that are injured, either before or after they have joined to form the lower trunk. Atrophy follows in the intrinsic muscles of the hand, and in the flexors of the fingers and wrist; the thenar and hypothenar eminences waste and flatten; the fingers cannot be spread out or approximated, on account of the paralysis of the Interossei, and become clawed.

The brachial plexus may also be injured by direct violence or a gunshot wound, by violent traction on the arm, or by efforts at reducing a dislocation of the shoulder-joint;

* According to Hutchison, the digital nerve to the thumb reaches only as far as the root of the nail; the one to the forefinger as far as the middle of the second phalanx; and those to the middle and ring fingers not farther than the first phalangeal joints.—*London Hospital Gazette*, vol. iii. p. 319.

and the amount of paralysis will depend upon the amount of injury to the constituent nerves. When the entire plexus is involved, the whole of the upper extremity will be paralysed and anæsthetic. In some cases the injury appears to be rather a tearing away of the roots of the nerves from the medulla spinalis than a rupture of the nerves themselves. The brachial plexus in the axilla is often damaged from the pressure of a crutch, producing the condition known as 'crutch paralysis.' In these cases the radial (musculospiral) is the nerve most frequently implicated; the ulnar nerve suffers next in frequency. The median and radial nerves often suffer from 'sleep palsies,' paralysis from pressure coming on while the patient is profoundly asleep under the influence of alcohol or some narcotic.

Paralysis of the *long thoracic nerve* throws the Serratus anterior out of action, and may occur in porters in whom the nerve is exposed to injury as it crosses the posterior triangle of the neck. The inferior angle of the scapula is drawn towards the middle line, by the unopposed action of the Rhomboidei and Levator scapulæ, and tends to project backwards when the arm is held horizontally forwards. The arm cannot be raised above the horizontal unless the inferior angle of the scapula is pushed lateralwards for the patient.

The *axillary* (*circumflex*) *nerve*, on account of its course round the surgical neck of the humerus, is liable to be torn in fractures of this part of the bone, and in dislocations of the shoulder-joint; paralysis of the Deltoideus, and anæsthesia of the skin over the lower part of that muscle, result. According to Erb, inflammation of the shoulder-joint is liable to be followed by a neuritis of this nerve from extension of the inflammation to it. Paralysis of the Deltoideus renders abduction of the arm to the horizontal level impossible. The associated paralysis of the Teres minor is not easily demonstrated.

Hilton gave the axillary nerve as an illustration of a law which he laid down, that 'the same trunks of nerves whose branches supply the groups of muscles moving a joint, furnish also a distribution of nerves to the skin over the insertions of the same muscles, and the interior of the joint receives its nerves from the same source.' In this way he explains the fact that an inflamed joint becomes rigid.

The *median nerve* is liable to injury in wounds of the forearm. In such cases there is loss of flexion of the second phalanges of all the fingers, and of the terminal phalanges of the index and middle fingers. Flexion of the terminal phalanges of the ring and little fingers is effected by that portion of the Flexor digitorum profundus which is supplied by the ulnar nerve. There is power to flex the proximal phalanges through the Interossei. The thumb cannot be flexed or opposed, and is maintained in a position of extension and adduction. There is loss in the power of pronating the forearm; the Brachioradialis has the power of bringing the forearm into a position of mid-pronation, but beyond this no further pronation can be effected. The wrist can be flexed, if the hand is first adducted by the action of the Flexor carpi ulnaris. There is loss or impairment of sensation on the volar surfaces of the thumb, index, middle, and radial half of the ring fingers, and on the dorsal surfaces of the same fingers over the last two phalanges; except in the thumb, where the loss of sensation would be limited to the back of the distal phalanx. In old cases the unopposed action of the Interossei produces backward dislocation of the interphalangeal joints. The thumb is extended and adducted to the index finger, cannot be flexed or abducted, and cannot be opposed to any one of the fingers; in consequence an 'ape-like' hand is produced. More commonly, however, the nerve is injured just above the annular ligament, when the power of flexion of the fingers and pronation of the forearm remains intact unless the flexor tendons are also divided. This injury seriously interferes with the use of the hand, as, besides the wasting of the muscles of the thenar eminence, great trouble is experienced from the trophic changes which result about the skin and nails of the fingers, which are anæsthetic. In order to expose the median nerve, for the purpose of uniting the divided ends, supposing the injury to be just above the wrist, an incision should be made along the radial side of the tendon of the Palmaris longus, which serves as a guide to the nerve.

The *ulnar nerve* is also liable to be injured in wounds of the forearm, such injury leading to impaired power of ulnar flexion, and upon an attempt being made to flex the wrist, the hand is drawn to the radial side from paralysis of the Flexor carpi ulnaris; there is inability to spread out the fingers from paralysis of the Interossei, and for the same reason the fingers, especially the ring and little fingers, cannot be flexed at the metacarpophalangeal joints or extended at the interphalangeal joints, and the hand assumes a claw shape from the action of the opposing muscles; there is loss of power of flexion in the little and ring fingers; and there is inability to adduct the thumb. The muscles of the hypothenar eminence become wasted. Sensation is lost, or impaired, in the skin supplied by the nerve. In order to expose the nerve in the lower part of the forearm, an incision should be made along the radial border of the tendon of the Flexor carpi ulnaris, and the nerve will be found lying on the medial side of the ulnar artery. This nerve may be also affected in cases of dislocation of the shoulder or fracture of the surgical neck of the humerus. Wasting of the muscles which it supplies is not uncommonly seen where a 'cervical rib' is present, the lower end of the plexus passing between this and the first thoracic rib.

The *radial* (*musculospiral*) *nerve* is also frequently injured. In consequence of its close relationship to the humerus, it is often torn or injured in fractures of this bone, or subsequently involved in the callus that may be thrown out around a fracture, and thus

pressed upon and its functions interfered with. It is also liable to be contused against the bone by kicks or blows, or to be divided in wounds of the arm. When paralysed, the hand is flexed at the wrist and lies flaccid. This is known as *wrist-drop*. The fingers are also flexed, and on an attempt being made to extend them, the last two phalanges only will be extended, through the action of the Lumbricales and Interossei; the first phalanges remaining flexed. There is no power of extending the wrist. Supination is completely lost when the forearm is extended on the arm, but is possible to a certain extent if the forearm be flexed so as to allow of the action of the Biceps brachii. The power of extension of the forearm is lost on account of paralysis of the Triceps brachii, if the injury to the nerve has taken place near its origin. In cases due to pressure, sensation is hardly affected; severe injury to the nerve occasions anæsthesia over the area supplied by the superficial branch of the radial nerve, and, if the lesion be high up, on the lateral side of the upper arm and the back of the forearm (posterior brachial and dorsal antibrachial cutaneous branches) as well. The muscles supplied by the deep branch of the radial nerve are also particularly liable to be affected in chronic lead-poisoning; here the affection is probably in the cells of the anterior column of the medulla spinalis.*

The radial nerve is best exposed by making an incision along the medial border of the Brachioradialis, just above the level of the elbow-joint. The skin and superficial fascia are to be divided and the deep fascia exposed. The white line in the fascia indicating the border of the muscle is to be defined, and the deep fascia divided in this line. On raising the Brachioradialis, the nerve will be found lying between it and the Brachialis. Incisions down to the neck of the radius posteriorly or on the lateral side should never be made, as the deep branch of the radial nerve would be severed.

The distribution of the cutaneous nerves on the hand and fingers is subject to considerable variation, and a knowledge of these is of some clinical importance. Stopford,† from an investigation of 1000 cases of gunshot wounds of the upper extremity, has described and tabulated most of the variations. Speaking generally the arrangement on the volar surface is fairly constant and conforms to that described in this text. On the dorsum of the hand and fingers there is greater variability, chiefly on the radial side where the superficial radial, the dorsal antibrachial cutaneous, and the lateral antibrachial cutaneous nerves all contribute in varying amounts to the supply.

THE ANTERIOR DIVISIONS OF THE THORACIC NERVES

The **anterior divisions of the thoracic nerves** (fig. 917) are twelve in number on either side. Eleven of them are situated between the ribs, and are therefore termed *intercostal*; the twelfth lies below the last rib. Each nerve is connected with the adjoining ganglion of the sympathetic trunk by a grey and a white ramus communicans. The intercostal nerves are distributed chiefly to the parietes of the thorax and abdomen, and differ from the anterior divisions of the other spinal nerves, in that each pursues an independent course, i.e. there is no plexus formation. The first two nerves supply fibres to the upper limb in addition to their thoracic branches; the next four are limited in their distribution to the parietes of the thorax; the lower five supply the parietes of the thorax and abdomen; the lower seven supply both motor and sensory fibres to the Diaphragm; the twelfth is distributed to the abdominal wall and the skin of the buttock.

The **first thoracic nerve.**—The anterior division of the first thoracic nerve divides into a large and a small branch. The large branch ascends in front of the neck of the first rib on the lateral side of the arteria intercostalis suprema, and enters the brachial plexus (p. 935). The small branch is the *first intercostal nerve*; it runs along the first intercostal space, and ends on the front of the chest as the first anterior cutaneous branch of the thorax. Occasionally this anterior cutaneous branch is wanting. The first intercostal nerve as a rule gives off no lateral cutaneous branch; but sometimes it sends a small branch to communicate with the intercostobrachial. The first thoracic nerve frequently receives a connecting twig from the second nerve; this twig ascends over the neck of the second rib.

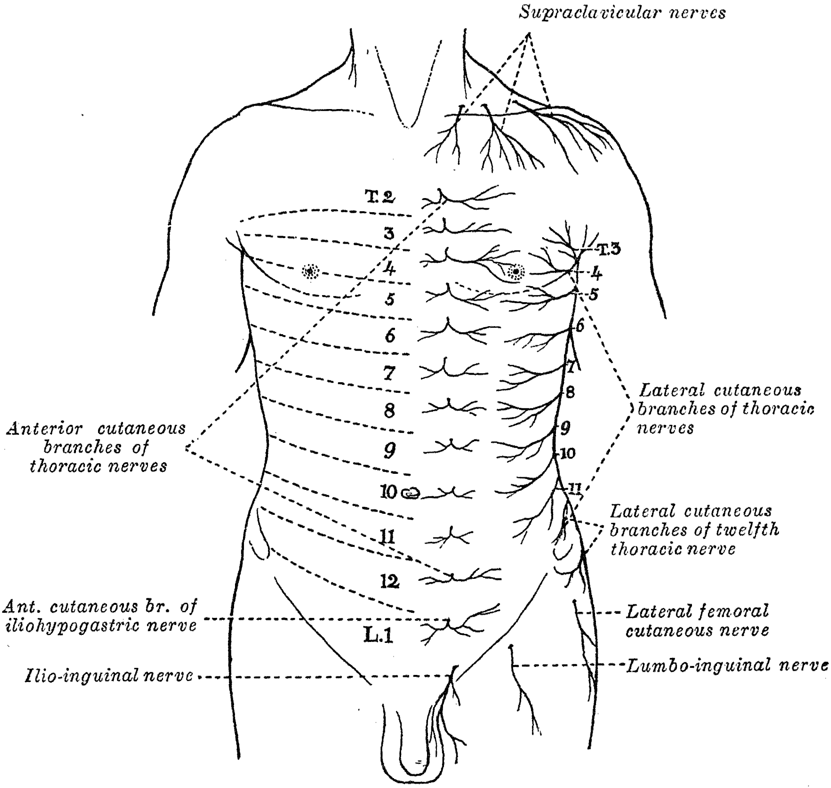
The **upper thoracic nerves.**—The anterior divisions of the second, third, fourth, fifth, and sixth thoracic nerves pass forwards (fig. 918) in the intercostal spaces below the intercostal vessels. At the back of the chest they lie between the pleura and the posterior intercostal membranes, but soon pierce the latter

* Consult an article on 'Voluntary movements in cases of nerve lesions,' by F. Wood Jones, *Journal of Anatomy*, vol. liv. part i.

† J. S. B. Stopford, *Journal of Anatomy*, vol. liii. Oct. 1918.

and run between the two planes of Intercostal muscles as far as the middle of the rib. They then enter the substance of the Intercostales interni, and, running amidst their fibres as far as the costal cartilages, they gain the inner surfaces of the muscles and lie between them and the pleura. Near the sternum, they cross in front of the internal mammary artery and Transversus thoracis muscle, pierce the Intercostales interni, the anterior intercostal membranes, and the Pectoralis major, and are now named the *anterior cutaneous nerves of the thorax*; they supply the skin of the mamma and of the front of the thorax; the branch from the second nerve unites with the anterior supraclavicular nerves of the cervical plexus.

FIG. 917.—A diagram showing the distribution of the cutaneous nerves on the front of the trunk.



Branches.—Numerous slender muscular filaments supply the Intercostales, the Subcostales, the Levatores costarum, the Serratus posterior superior, and the Transversus thoracis. At the front of the thorax some of these branches cross the costal cartilages from one intercostal space to another.

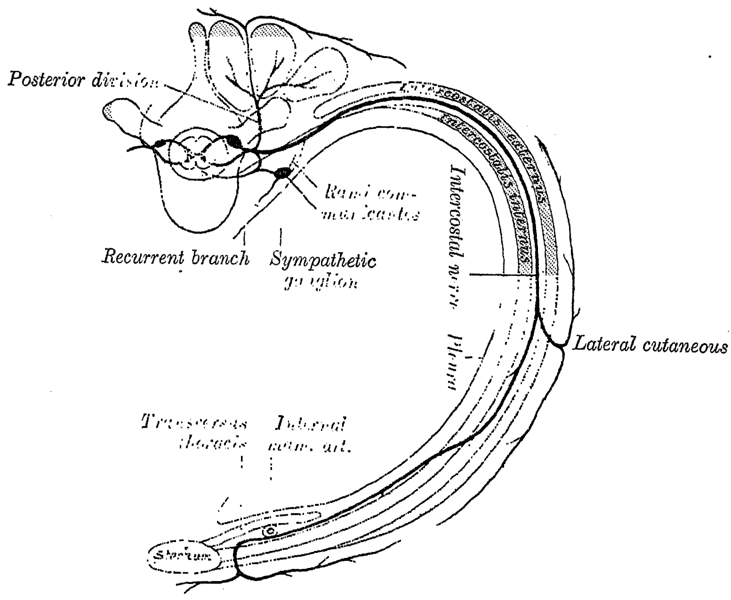
Each of these intercostal nerves, except the first, sends off a *lateral cutaneous branch*, about midway between the vertebral column and the sternum. These branches pierce the Intercostales externi, pass between the digitations of the Serratus anterior, and, with the exception of the lateral cutaneous branch of the second intercostal nerve, divide into anterior and posterior branches. The *anterior branches* run forwards over the border of the Pectoralis major and supply twigs to the skin and the mamma; those of the fifth and sixth nerves supply twigs to the upper digitations of the Obliquus externus abdominis. The *posterior branches* run backwards, and supply the skin over the scapula and Latissimus dorsi.

The lateral cutaneous branch of the second intercostal nerve is named the *intercostobrachial nerve* (fig. 915). It crosses the axilla to the medial side of the arm, and joins with a filament from the medial brachial cutaneous nerve.

It then pierces the fascia brachii, and supplies the skin of the upper half of the medial and posterior parts of the arm, communicating with the posterior brachial cutaneous branch of the radial nerve. The size of the intercostobrachial nerve is in inverse proportion to that of the medial brachial cutaneous nerve. A second intercostobrachial nerve is frequently given off from the anterior part of the lateral cutaneous branch of the third intercostal nerve; it supplies filaments to the axilla and medial side of the arm.

The **lower thoracic nerves.**—The anterior divisions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves are continued anteriorly from the intercostal spaces into the abdominal wall. They have the same arrangement as the upper ones as far as the anterior ends of the intercostal spaces, where they pass between the origins of the Diaphragm and the Transversus abdominis into the abdominal wall, and running forwards between the

FIG. 918.—A diagram of the course and branches of a typical intercostal nerve.



Obliquus internus and Transversus abdominis, enter the sheath of the Rectus abdominis. They supply the Rectus abdominis and end as the *anterior cutaneous nerves*, which are distributed to the skin of the front of the abdomen. The lower intercostal nerves supply the Intercostales and the abdominal muscles, and the last three send branches to the Serratus posterior inferior. About the middle of their course they give off *lateral cutaneous branches*; these pierce the Intercostales externi and the Obliquus externus abdominis, in the same line as the lateral cutaneous branches of the upper thoracic nerves, and divide into anterior and posterior branches, which are distributed to the skin of the abdomen and back respectively; the anterior branches also supply twigs to the digitations of the Obliquus externus abdominis, and extend downwards and forwards nearly as far as the margin of the Rectus abdominis; the posterior branches pass backwards to supply the skin over the Latissimus dorsi.

The anterior division of the **twelfth thoracic nerve** is larger than the others, and often gives a communicating branch to the first lumbar nerve. It accompanies the subcostal artery along the lower border of the twelfth rib, and passes under the lateral lumbocostal arch. It then runs behind the kidney, and in front of the upper part of the Quadratus lumborum, perforates the posterior aponeurosis of the Transversus, and passes forwards between that muscle and the Obliquus internus, to be distributed in the same manner as the lower intercostal nerves. It communicates with the iliohypogastric nerve of

the lumbar plexus, and gives a branch to the Pyramidalis. The *lateral cutaneous branch* of the twelfth thoracic nerve pierces the Obliquus internus and Obliquus externus, gives a twig to the lowest slip of the latter muscle, descends over the iliac crest about 5 cm. behind the anterior superior iliac spine (fig. 925), and is distributed to the skin of the front part of the buttock, some of its filaments reaching as low as the greater trochanter of the femur.

Applied Anatomy.—The lower seven thoracic nerves and the iliohypogastric branch of the first lumbar nerve supply the skin of the abdominal wall. They run downwards and forwards fairly equidistant from each other. The sixth and seventh supply the skin over the 'pit of the stomach'; the eighth corresponds to about the position of the middle tendinous inscription of the Rectus abdominis; the tenth to the umbilicus; the iliohypogastric supplies the skin over the os pubis and subcutaneous inguinal ring. In many diseases affecting the nerve-trunks at or near their origins, the pain is referred to their peripheral terminations. Thus, in Pott's disease of the vertebræ, children often suffer from pain in the abdomen. When the irritation is confined to a single pair of nerves, the sensation complained of is often a feeling of constriction, as if a cord were tied round the abdomen, and in these cases the situation of the sense of constriction may serve to localise the disease in the vertebral column. Where the bone disease is more extensive and two or more nerves are involved, a more general, diffused pain in the abdomen is felt.

Again, it must be borne in mind that the nerves which supply the skin of the abdomen supply also the planes of muscle which constitute the greater part of the abdominal wall. Hence, any irritation applied to the peripheral ends of the cutaneous branches in the skin of the abdomen is immediately followed by reflex contraction of the abdominal muscles. The supply of both muscles and skin from the same source is of importance in protecting the abdominal viscera from injury. A blow on the abdomen, even of a severe character, will do no injury to the viscera if the muscles are in a condition of firm contraction; whereas in cases where the muscles have been taken unawares, and the blow has been struck while they were in a state of rest, an injury insufficient to produce any lesion of the abdominal wall has been attended with rupture of some of the abdominal contents. The importance, therefore, of immediate reflex contraction upon the receipt of an injury cannot be overestimated, and the intimate association of the cutaneous and muscular fibres in the same nerve produces a much more rapid response on the part of the muscles to any peripheral stimulation of the cutaneous filaments than would be the case if the two sets of fibres were derived from independent sources.

The nerves supplying the abdominal muscles and skin, derived from the lower intercostal nerves, are intimately connected with the sympathetic supplying the abdominal viscera through the lower thoracic ganglia from which the splanchnic nerves are derived. In consequence of this, in laceration of the abdominal viscera and in acute peritonitis, the muscles of the belly wall become firmly contracted, and thus as far as possible preserve the abdominal contents in a condition of rest.

THE ANTERIOR DIVISIONS OF THE LUMBAR NERVES

The **anterior divisions of the lumbar nerves** increase in size from the first to the last. They are joined, near their origins, by *grey rami communicantes* from the lumbar ganglia of the sympathetic trunk. These rami consist of long, slender branches which accompany the lumbar arteries round the sides of the vertebral bodies, beneath the Psoas major. Their arrangement is somewhat irregular: one ganglion may give rami to two lumbar nerves, or one lumbar nerve may receive rami from two ganglia. The first and second, and sometimes the third and fourth, lumbar nerves are each connected with the lumbar part of the sympathetic trunk by a *white ramus communicans.*

The anterior divisions of the lumbar nerves pass obliquely outwards behind the Psoas major, or between its fasciculi. The first three nerves and the greater part of the fourth, form the *lumbar plexus.* The smaller part of the fourth nerve joins with the fifth to form the *lumbosacral trunk,* which assists in the formation of the sacral plexus. The fourth nerve is named the *nervus furcalis*, from the fact that it is subdivided between the two plexuses.*

* In most cases the fourth lumbar is the *nervus furcalis*; but this arrangement is frequently departed from. The third is occasionally the lowest nerve which enters the lumbar plexus, giving at the same time some fibres to the sacral plexus, and thus forming the nervus furcalis; or both the third and fourth may be furcal nerves. When this occurs, the plexus is termed *high* or *prefixed.* More frequently the fifth nerve is divided between the lumbar and sacral plexuses, and constitutes the nervus furcalis; and when this takes place, the plexus is distinguished as a *low* or *postfixed* plexus. These variations necessarily produce corresponding modifications in the sacral plexus.

The Lumbar Plexus

The **lumbar plexus** (fig. 919) is situated in the posterior part of the Psoas major, in front of the transverse processes of the lumbar vertebræ ; it is formed by the anterior divisions of the first three, and the greater part of the anterior division of the fourth, lumbar nerves ; the first lumbar nerve receives a branch from the last thoracic nerve.

The mode in which it is arranged varies in different subjects, but the usual condition is the following. The first lumbar nerve, supplemented by a twig from the last thoracic, splits into an upper and a lower branch ; the upper, larger branch divides into the iliohypogastric and ilio-inguinal nerves ; the lower, smaller branch unites with a branch of the second lumbar to form the genitofemoral nerve. The remainder of the second nerve, the third nerve, and the part of the fourth nerve which joins the plexus, divide into ventral and dorsal branches. The ventral branch of the second unites with the ventral branches of the third and fourth nerves to form the obturator nerve. The dorsal branches of the second and third nerves each divide into a smaller and larger part, the smaller parts uniting to form the lateral femoral cutaneous nerve, and the larger parts joining with the dorsal branch of the fourth nerve to form the femoral nerve. The accessory obturator, when it exists, arises from the ventral branches of the third and fourth nerves.

The branches of the lumbar plexus may therefore be arranged as follows :

Muscular.	
Iliohypogastric	1 L.
Ilio-inguinal	1 L.
Genitofemoral	1, 2 L.
	Dorsal divisions.
Lateral femoral cutaneous	2, 3 L.
Femoral	2, 3, 4 L.
	Ventral divisions.
Obturator	2, 3, 4 L.
Accessory obturator	3, 4 L.

Muscular branches are distributed to the Quadratus lumborum from the twelfth thoracic and first three or four lumbar nerves; to the Psoas minor from the first, and to the Psoas major and Iliacus from the second, third and fourth, lumbar nerves.

The **iliohypogastric nerve** arises from the first lumbar nerve. It emerges from the upper part of the lateral border of the Psoas major, and crosses obliquely behind the kidney, and in front of the Quadratus lumborum to the iliac crest. It then perforates the posterior part of the Transversus abdominis, and divides between that muscle and the Obliquus internus abdominis into a lateral and an anterior cutaneous branch.

The *lateral cutaneous branch* pierces the Obliquus internus and Obliquus externus immediately above the iliac crest at a point a little behind the iliac branch of the twelfth thoracic nerve; it is distributed to the skin of the anterior part of the side of the buttock.

The *anterior cutaneous branch* (fig. 917) runs between the Obliquus internus and Transversus, supplying twigs to both muscles. It then pierces the Obliquus internus at a point about 2 cm. on the medial side of the anterior superior iliac spine, perforates the aponeurosis of the Obliquus externus about 3 cm. above the subcutaneous inguinal ring, and is distributed to the skin of the abdomen above the os pubis.

The iliohypogastric nerve communicates with the last thoracic and ilio-inguinal nerves.

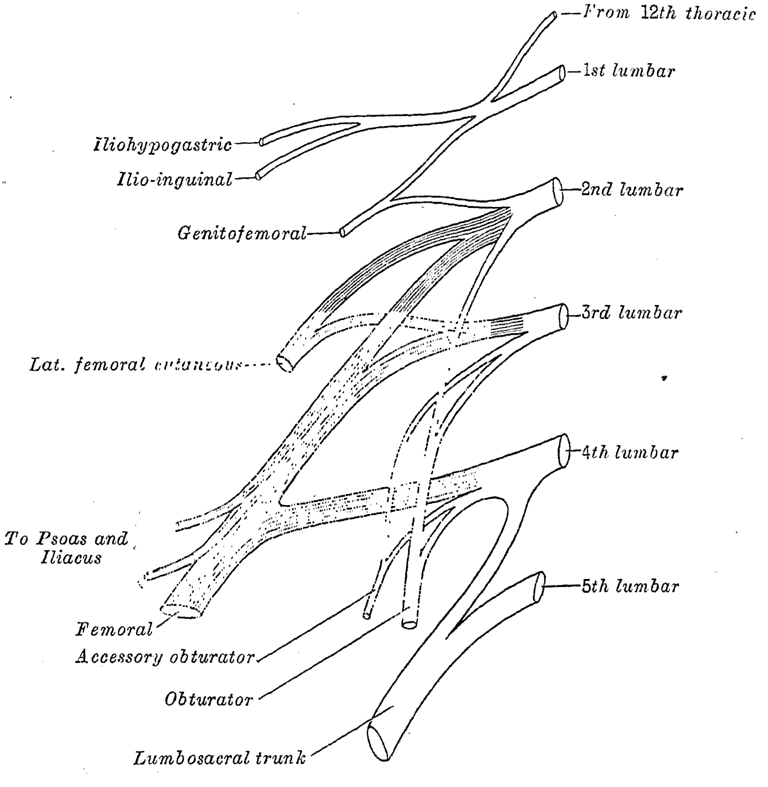
The **ilio-inguinal nerve,** smaller than the iliohypogastric nerve, arises with it from the first lumbar nerve. It emerges from the lateral border of the Psoas major just below the iliohypogastric nerve, and, passing obliquely across the Quadratus lumborum and Iliacus, perforates the Transversus abdominis, near the anterior part of the iliac crest, and communicates with the iliohypogastric nerve. It then pierces the Obliquus internus, distributing filaments to it, and, accompanying the spermatic cord through the subcutaneous inguinal

ring, is distributed to the skin of the upper and medial part of the thigh, to the skin over the root of the penis and upper part of the scrotum in the male, and to the skin covering the mons pubis (mons Veneris) and labium majus in the female.

The size of the ilio-inguinal nerve is in inverse proportion to that of the iliohypogastric. Occasionally it is very small, and ends by joining the iliohypogastric nerve; in such cases, a branch from the iliohypogastric takes the place of the ilio-inguinal, or the latter nerve may be altogether absent.

The **genitofemoral nerve** (genitocrural nerve) arises from the first and second lumbar nerves. It passes obliquely forwards and downwards through

FIG. 919.—A plan of the lumbar plexus.



the substance of the Psoas major, and emerges near its medial border, opposite the fibrocartilage between the third and fourth lumbar vertebræ; it then descends on the surface of the Psoas major, under cover of the peritoneum, and divides into the external spermatic and lumbo-inguinal nerves. The genitofemoral nerve frequently divides close to its origin, and the external spermatic and lumbo-inguinal nerves then emerge separately through the Psoas major.

The *external spermatic nerve* (genital branch of genitocrural) passes lateralwards on the Psoas major, and pierces the fascia transversalis, or passes through the abdominal inguinal ring; it then descends behind the spermatic cord, supplies the Cremaster, and gives a few filaments to the skin of the scrotum. In the female, it accompanies the round ligament of the uterus and ends in the skin of the mons pubis and labium majus.

The *lumbo-inguinal nerve* (crural branch of genitocrural) descends on the external iliac artery, sending a few filaments round it, and, passing beneath the inguinal ligament, enters the femoral sheath, lying superficial and lateral to the femoral artery. It pierces the anterior layer of the femoral sheath and the fascia lata, and supplies a limited area of the skin on the anterior

surface of the upper part of the thigh (fig. 920). On the front of the thigh it communicates with the intermediate cutaneous branch of the femoral nerve.

FIG. 920.—The cutaneous nerves of the right lower extremity. Anterior aspect.

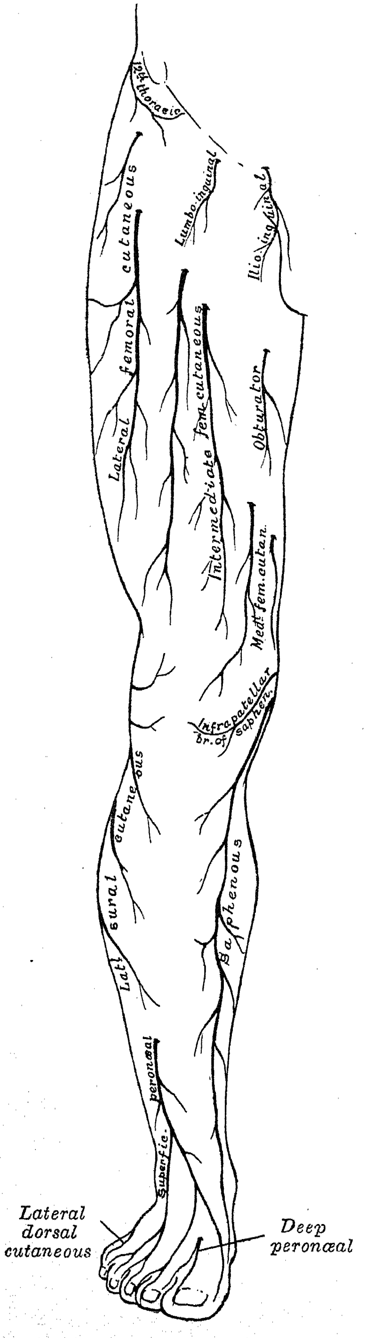
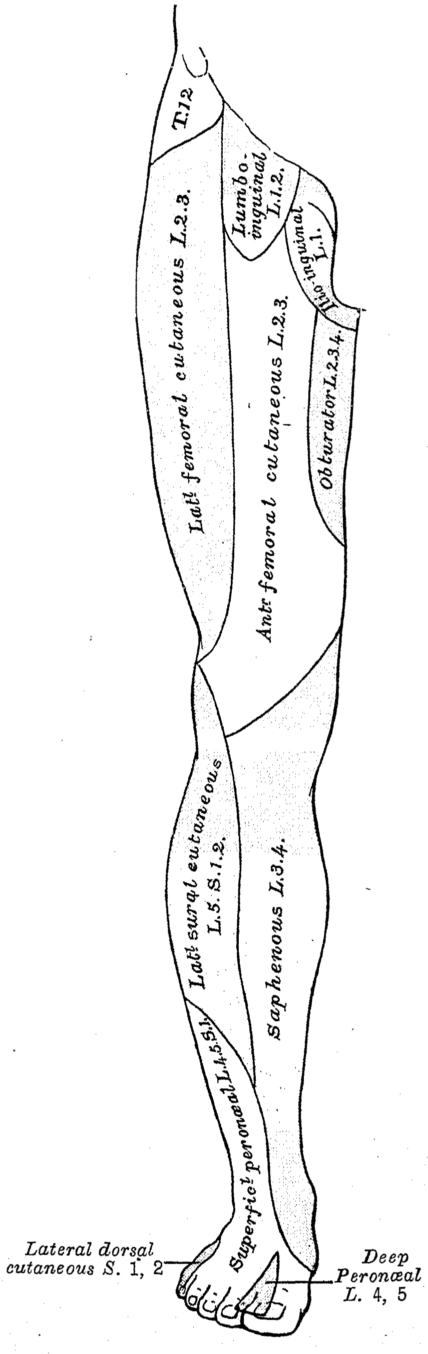


FIG. 921.—A diagram showing the segmental distribution of the cutaneous nerves of the right lower extremity. Anterior aspect.



As the nerve runs beneath the inguinal ligament it gives a few twigs to the femoral artery.

The **lateral femoral cutaneous nerve** (external cutaneous nerve) arises from the dorsal branches of the anterior divisions of the second and third lumbar nerves. It emerges from the lateral border of the Psoas major, and crosses the Iliacus obliquely, towards the anterior superior iliac spine. It then passes under the inguinal ligament and over or through the Sartorius into the thigh, where it divides into an anterior and a posterior branch (fig. 920).

The *anterior branch* becomes superficial about 10 cm. below the anterior superior iliac spine, and is distributed to the skin of the anterior and lateral parts of the thigh, as far as the knee. Its terminal filaments frequently communicate with the anterior cutaneous branches of the femoral nerve, and with the infrapatellar branch of the saphenous nerve, forming with them the *patellar plexus.*

The *posterior branch* pierces the fascia lata at a higher level than the anterior branch, and subdivides into filaments which pass backwards to supply the skin on the lateral surface of the limb, from the level of the greater trochanter to about the middle of the thigh.

The **obturator nerve** arises from the ventral branches of the anterior divisions of the second, third, and fourth lumbar nerves; the branch from the third is the largest, while that from the second is often very small. It descends through the fibres of the Psoas major, and emerges from its medial border at the brim of the pelvis; it then passes behind the common iliac vessels, and on the lateral side of the hypogastric vessels, and runs along the lateral wall of the lesser pelvis, above and in front of the obturator vessels, to the upper part of the obturator foramen, through which it enters the thigh. At the foramen it divides into an anterior and a posterior branch, which are separated at first by a few fibres of the Obturator externus, and lower down by the Adductor brevis.

The *anterior branch* (fig. 922) leaves the pelvis in front of the Obturator externus and descends in front of the Adductor brevis, and behind the Pectineus and Adductor longus; at the lower border of the latter muscle it communicates with the medial cutaneous and saphenous branches of the femoral nerve, forming a kind of plexus. It then descends upon the femoral artery, to which it is finally distributed. Near the obturator foramen this branch gives an articular twig to the hip-joint. Behind the Pectineus, it distributes branches to the Adductor longus and Gracilis, and usually to the Adductor brevis, and in rare cases to the Pectineus; it receives a filament from the accessory obturator nerve when that nerve is present.

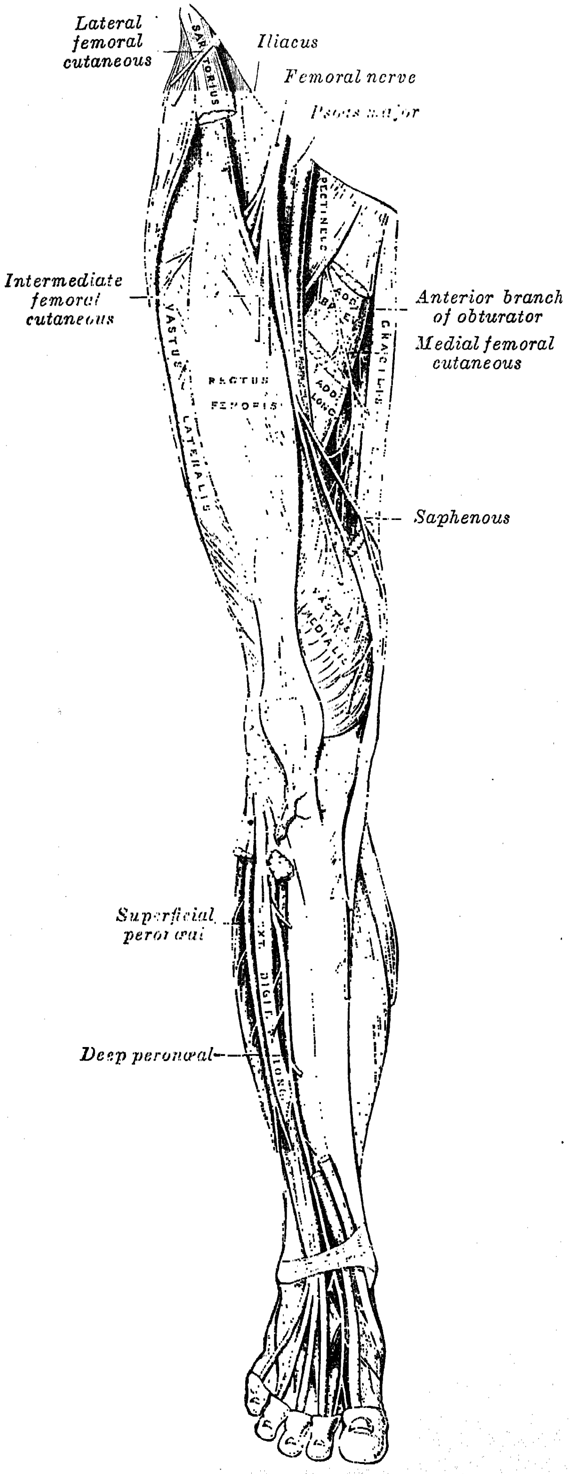
Occasionally the communicating branch to the medial cutaneous and saphenous branches of the femoral nerve is continued down, as a cutaneous branch, to the thigh and leg. When this is so, it emerges from beneath the lower border of the Adductor longus, descends along the posterior margin of the Sartorius to the medial side of the knee, where it pierces the deep fascia, communicates with the saphenous nerve, and is distributed to the skin half-way down the medial side of the leg.

The *posterior branch* pierces the anterior part of the Obturator externus, and supplies this muscle; it then passes behind the Adductor brevis on the front of the Adductor magnus, and divides into branches which are distributed to the Adductor magnus and to the Adductor brevis when the latter does not receive a branch from the anterior division of the nerve. It frequently gives a slender *articular branch* to the knee-joint; this branch perforates the lower part of the Adductor magnus or passes through the opening which transmits the femoral artery, and enters the popliteal fossa; it here descends upon the popliteal artery, to the back of the knee-joint, where it pierces the oblique popliteal ligament, and is distributed to the articular capsule. It gives filaments to the popliteal artery.

The **accessory obturator nerve** (fig. 919) is present in about 29 per cent. of subjects. It is of small size, and arises from the ventral branches of the anterior divisions of the third and fourth lumbar nerves. It descends along the medial border of the Psoas major, crosses the superior ramus of the os pubis behind the Pectineus, and divides into branches. One branch enters the deep surface of the Pectineus; another goes to the hip-joint; while a third communicates with the anterior branch of the obturator nerve. Occasionally the accessory obturator nerve is very small and supplies only the Pectineus.

The femoral nerve (anterior crural nerve) (fig. 922), the largest branch of the lumbar plexus, arises from the dorsal branches of the anterior divisions of the second, third, and fourth lumbar nerves. It descends through the fibres of the Psoas major, emerging from the muscle at the lower part of its lateral border, and passes down between it and the Iliacus, behind the iliac fascia; it then runs beneath the inguinal ligament, into the thigh, and splits into an anterior and a posterior division. Under the inguinal ligament, it is separated from the femoral artery by a portion of the Psoas major.

FIG. 922.—The nerves of the right lower extremity. Anterior aspect.



Within the abdomen the femoral nerve gives off small branches to the Iliacus, and a branch which is distributed upon the upper part of the femoral artery; the latter branch may arise in the thigh.

The anterior division of the femoral nerve gives off the intermediate and medial cutaneous nerves (fig. 920), and muscular branches to the Pectineus and Sartorius.

The *intermediate cutaneous nerve* pierces the fascia lata about 8 cm. below the inguinal ligament, either as two branches, or as a single trunk which quickly divides into two branches; these branches descend vertically along the front of the thigh, and supply the skin as low as the knee. They end in the patellar plexus (p. 957). The lateral branch of the intermediate cutaneous communicates with the lumbo-inguinal branch of the genitofemoral nerve, and frequently pierces the Sartorius.

The *medial cutaneous nerve* lies at first on the lateral side of the femoral artery, but at the apex of the femoral triangle it crosses in front of the artery and divides into an anterior and a posterior branch. Before dividing, the nerve

The Posterior Divisions of the Thoracic Nerves

The *medial* branches of the **posterior divisions of the upper six thoracic nerves** run between the Semispinalis dorsi and Multifidus, which they supply; they then pierce the Rhomboidei and Trapezius, and reach the skin by the sides of the spinous processes (fig. 907). The medial branches of the **lower six thoracic nerves** are distributed chiefly to the Multifidus and Longissimus dorsi; occasionally they give filaments to the skin near the middle line.

The *lateral* branches increase in size from above downwards. They run through or beneath the Longissimus dorsi to the interval between it and the Iliocostalis, and supply these muscles; the lower five or six also give off cutaneous branches which pierce the Serratus posterior inferior and Latissimus dorsi in a line with the angles of the ribs (fig. 907). The lateral branches of a variable number of the upper thoracic nerves also give filaments to the skin. The lateral branch of the twelfth thoracic, after sending a filament medialwards along the iliac crest, passes downwards to the skin of the anterior part of the buttock.

The medial cutaneous branches of the posterior divisions of the thoracic nerves descend for some distance close to the spinous processes before reaching the skin, while the lateral branches travel downwards for a considerable distance—it may be as much as the breadth of four ribs—before they become superficial; the branch from the twelfth thoracic, for instance, reaches the skin only a little way above the iliac crest.*

The Posterior Divisions of the Lumbar Nerves

The *medial* branches of the **posterior divisions of the lumbar nerves** run close to the articular processes of the vertebræ and end in the Multifidus.

The *lateral* branches supply the Sacrospinalis. The upper three give off cutaneous nerves which pierce the aponeurosis of the Latissimus dorsi at the lateral border of the Sacrospinalis and cross the posterior part of the iliac crest to the skin of the buttock (fig. 907), some of their twigs running as far as the level of the greater trochanter.

The Posterior Divisions of the Sacral Nerves

The **posterior divisions of the sacral nerves** are small, and diminish in size from above downwards; they emerge, except the last, through the posterior sacral foramina. The *upper three* are covered at their points of exit by the Multifidus, and divide into medial and lateral branches.

The *medial* branches are small, and end in the Multifidus.

The *lateral* branches join with one another and with the lateral branches of the posterior divisions of the last lumbar and fourth sacral to form loops on the dorsal surface of the sacrum. From these loops branches run to the dorsal surface of the sacrotuberous ligament and form a second series of loops under the Glutæus maximus. From this second series of loops cutaneous nerves (nn. clunium medii), two or three in number, pierce the Glutæus maximus along a line drawn from the posterior superior iliac spine to the tip of the coccyx; they supply the skin over the posterior part of the buttock (fig. 907).

The posterior divisions of the *lower two* sacral nerves are small and lie below the Multifidus. They do not divide into medial and lateral branches, but unite with each other and with the posterior division of the coccygeal nerve to form loops on the back of the sacrum; filaments from these loops supply the skin over the coccyx.

The Posterior Division of the Coccygeal Nerve

The **posterior division of the coccygeal nerve** does not divide into a medial and a lateral branch, but receives, as already stated, a communicating branch from the last sacral; it is distributed to the skin over the back of the coccyx.

* H. M. Johnston, *Journal of Anatomy and Physiology*, vol. xliii.

THE ANTERIOR DIVISIONS OF THE SACRAL AND COCCYGEAL NERVES

The **anterior divisions of the sacral and coccygeal nerves** form the sacral and pudendal plexuses. The anterior divisions of the upper four sacral nerves enter the pelvis through the anterior sacral foramina, that of the fifth between the sacrum and coccyx, while that of the coccygeal nerve curves forwards below the rudimentary transverse process of the first piece of the coccyx. The first and second sacral nerves are large; the third, fourth and fifth diminish progressively; the coccygeal nerve is the smallest. Each of these nerves receives a grey ramus communicans from the corresponding ganglion of the sympathetic trunk; from the second, third and fourth sacral nerves white rami communicantes are given to the pelvic plexuses of the sympathetic.

The Sacral Plexus

The **sacral plexus** (fig. 923) is formed by the lumbosacral trunk, the anterior division of the first, and portions of the anterior divisions of the second and third sacral nerves.

The lumbosacral trunk comprises a part of the anterior division of the fourth lumbar nerve, and the whole of the anterior division of the fifth lumbar nerve; it appears at the medial margin of the Psoas major and descends over the pelvic brim and in front of the sacro-iliac joint to join the first sacral nerve.

The anterior division of the third sacral nerve divides into an upper and a lower branch; the upper branch enters the sacral plexus; the lower joins the pudendal plexus.

The nerves forming the sacral plexus converge towards the lower part of the greater sciatic foramen, and unite to form a flattened band, from the anterior and posterior surfaces of which several branches arise; the band itself is continued as the sciatic nerve.

Relations.—The sacral plexus lies on the posterior wall of the pelvic cavity in front of the Piriformis (fig. 924), and behind the hypogastric vessels, the ureter and the sigmoid colon. The superior glutæal vessels run between the lumbosacral trunk and the anterior division of the first sacral nerve, and the inferior glutæal vessels between the anterior divisions of the second and third sacral nerves.

All the nerves entering the plexus, with the exception of the anterior division of the third sacral, split into ventral and dorsal divisions, and the nerves arising from these are as follows:

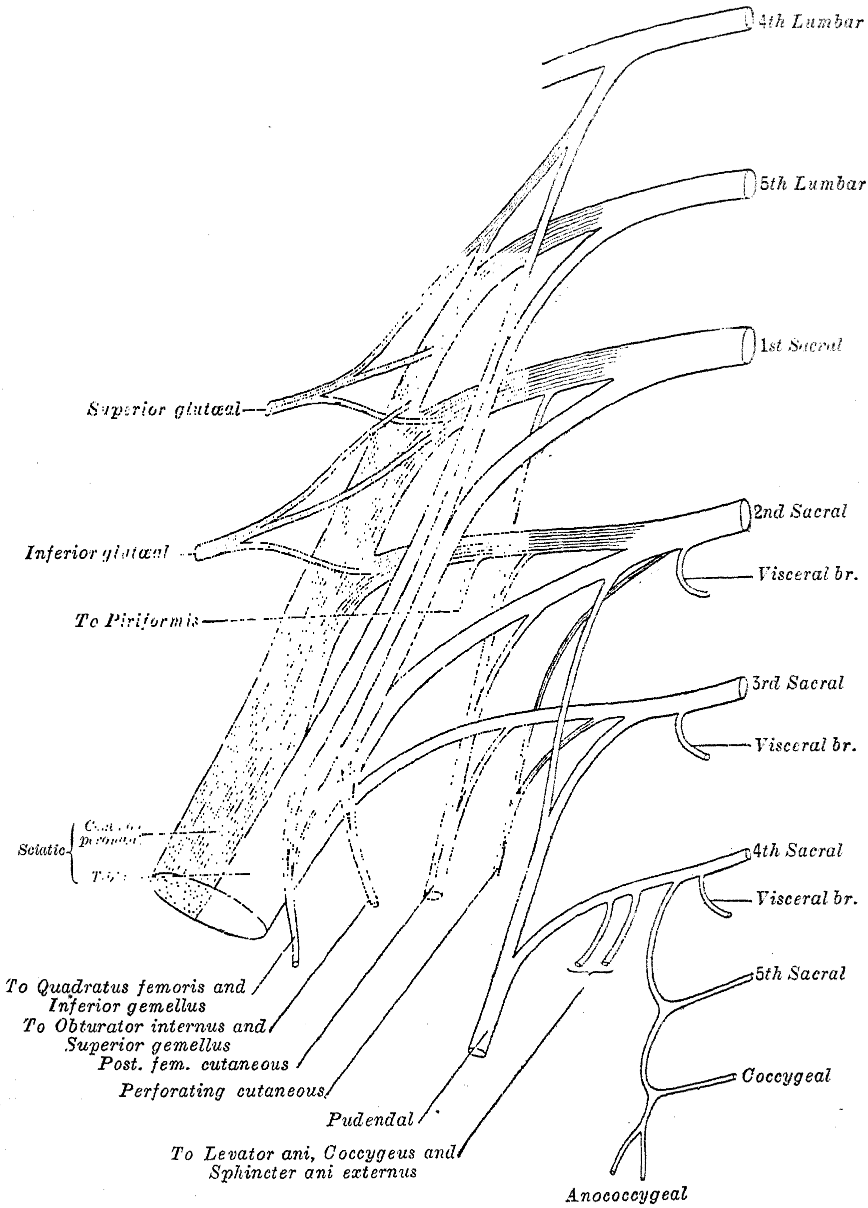
	Ventral divisions.	Dorsal divisions.
Nerve to Quadratus femoris and Gemellus inferior	4, 5 L., 1 S.	
Nerve to Obturator internus and Gemellus superior	5 L., 1, 2 S.	
Nerve to Piriformis		(1) 2 S.
Superior glutæal		4, 5 L., 1 S.
Inferior glutæal		5 L., 1, 2 S.
Posterior femoral cutaneous	2, 3 S.	1, 2 S.
Sciatic — Tibial	4, 5 L., 1, 2, 3 S.	
Sciatic — Common peronæal		4, 5 L., 1, 2 S.

The **nerve to the Quadratus femoris and Gemellus inferior** arises from the ventral branches of the anterior divisions of the fourth and fifth lumbar and first sacral nerves; it leaves the pelvis through the greater sciatic foramen, below the Piriformis, and, running down on the ischium in front of the sciatic nerve, the Gemelli and the tendon of the Obturator internus, supplies a twig to the Gemellus inferior, and enters the anterior surface of the Quadratus femoris; it gives an articular branch to the hip-joint.

The **nerve to the Obturator internus and Gemellus superior** arises from the ventral branches of the anterior divisions of the fifth lumbar and first and second sacral

nerves. It leaves the pelvis through the greater sciatic foramen below the Piriformis, and gives a branch which enters the upper part of the posterior surface of the Gemellus superior. It then crosses the ischial spine on the lateral side of the

Fig. 923.—A plan of the sacral and pudendal plexuses.



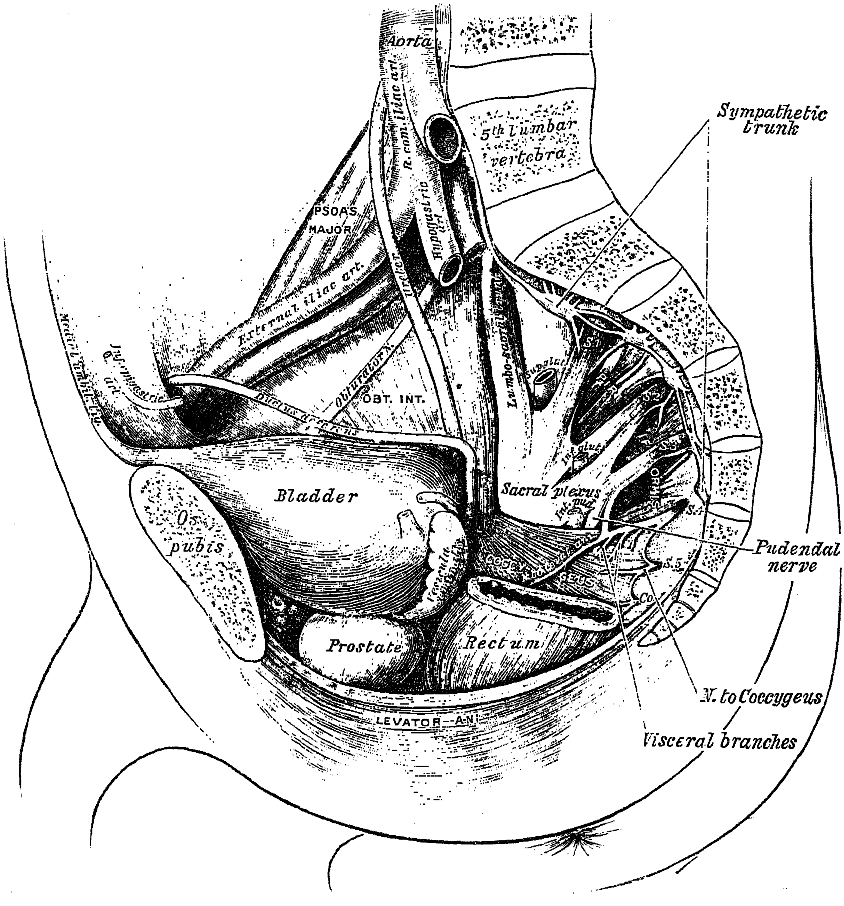
internal pudendal vessels, re-enters the pelvis through the lesser sciatic foramen, and pierces the pelvic surface of the Obturator internus.

The **nerve to the Piriformis** arises usually from the dorsal branches of the anterior divisions of the first and second sacral nerves ; it enters the anterior surface of the muscle.

The **superior glutæal nerve** arises from the dorsal branches of the anterior divisions of the fourth and fifth lumbar and first sacral nerves : it leaves the pelvis through the greater sciatic foramen above the Piriformis, accompanied by the

superior glutæal vessels, and divides into a superior and an inferior branch. The *superior* branch accompanies the upper branch of the deep division of the superior glutæal artery and ends in the Glutæus minimus. The *inferior* branch runs with the lower branch of the deep division of the superior glutæal artery across the Glutæus minimus; it gives twigs to the Glutæus medius and Glutæus minimus, and ends in the Tensor fasciæ latæ.

Fig. 924.—A dissection of the side wall of the pelvis, showing the sacral and pudendal plexuses.



The **inferior glutæal nerve** arises from the dorsal branches of the anterior divisions of the fifth lumbar and first and second sacral nerves: it leaves the pelvis through the greater sciatic foramen, below the Piriformis, and divides into branches which enter the deep surface of the Glutæus maximus.

The **posterior femoral cutaneous nerve** (small sciatic nerve) arises from the dorsal branches of the anterior divisions of the first and second, and from the ventral branches of the anterior divisions of the second and third, sacral nerves, and issues from the pelvis through the greater sciatic foramen below the Piriformis. It then descends beneath the Glutæus maximus with the inferior glutæal artery, and runs down the back of the thigh, superficial to the long head of the Biceps femoris, and beneath the fascia lata; at the back of the knee it pierces the deep fascia and accompanies the small saphenous vein as far as the middle of the calf of the leg, its terminal twigs communicating with the sural nerve.

Its branches are all cutaneous, and are distributed to the glutæal region, the perinæum, and the back of the thigh and leg.

Fig. 925.—The cutaneous nerves of the right lower extremity. Posterior aspect.

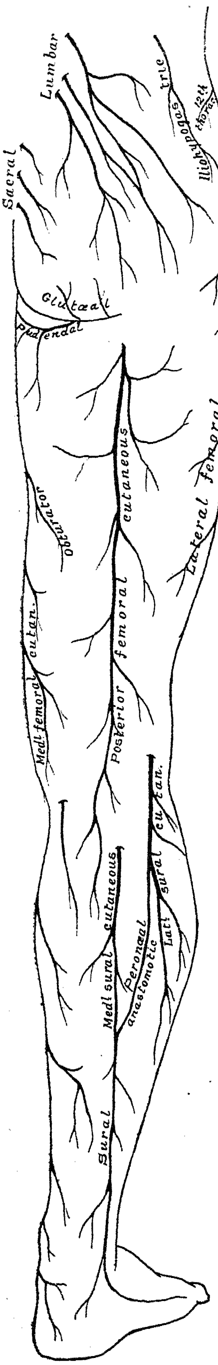
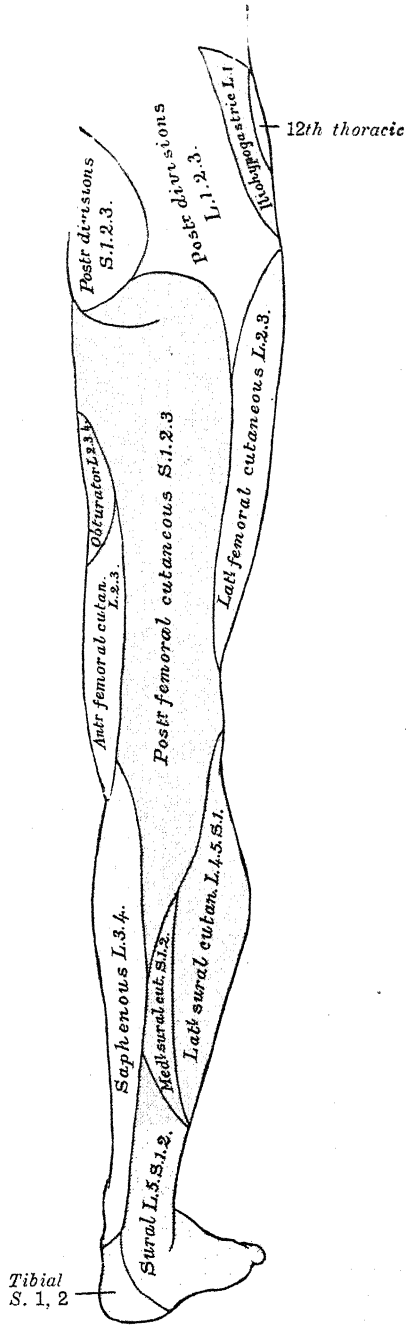


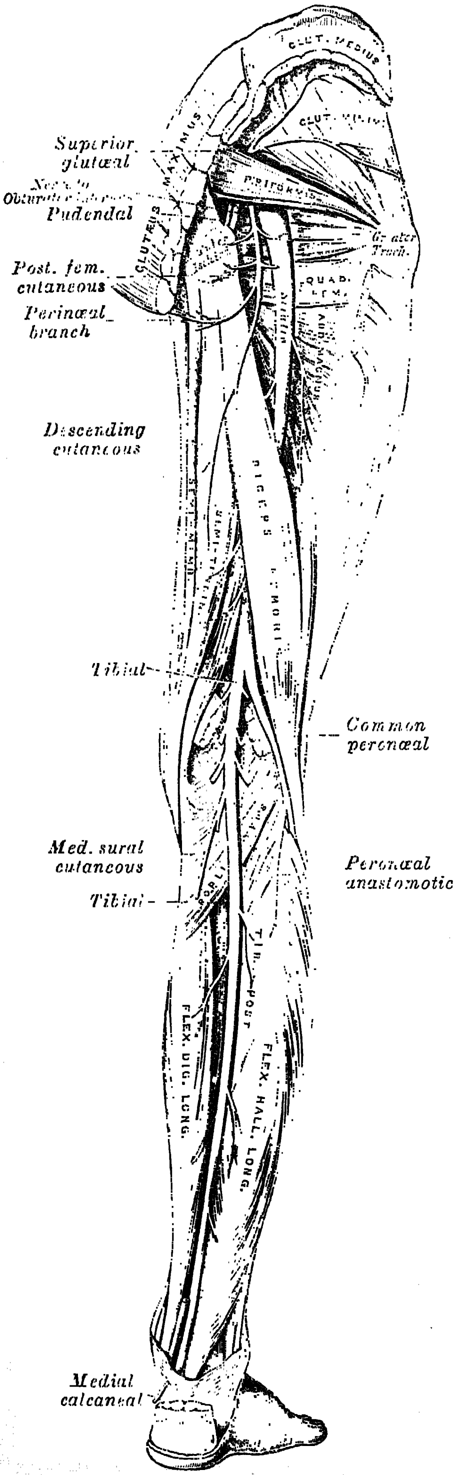
Fig. 926.—A diagram showing the segmental distribution of the cutaneous nerves of the right lower extremity. Posterior aspect.



The *glutæal branches* (nn. clunium inferiores), three or four in number, turn upwards round the lower border of the Glutæus maximus, and supply the skin covering the lower and lateral part of that muscle.

The *perinæal branches* are distributed to the skin at the upper and medial side of the thigh. One long perinæal branch (inferior pudendal) curves forwards

Fig. 927.—The nerves of the right lower extremity.* Posterior aspect.



below and in front of the ischial tuberosity, pierces the fascia lata, and runs forwards beneath the superficial fascia of the perinæum to the skin of the scrotum in the male, and of the labium majus in the female. It communicates with the inferior hæmorrhoidal and posterior scrotal nerves.

The *branches to the back of the thigh and leg* consist of numerous filaments derived from both sides of the nerve, and distributed to the skin covering the back and medial side of the thigh, the popliteal fossa, and the upper part of the back of the leg (fig. 925).

The **sciatic nerve** (fig. 927) is the largest nerve in the body. At its commencement it measures 2 cm. in breadth, and is the continuation of the flattened band of the sacral plexus. It passes out of the pelvis through the greater sciatic foramen, below the Piriformis muscle, descends between the greater trochanter of the femur and the tuberosity of the ischium, and along the back of the thigh to about its lower one-third, where it divides into two large branches, the tibial and common peronæal nerves. This division may take place at any point between the sacral plexus and the lower one-third of the thigh, and in all cases the independence of the two nerves can be shown by dissection. When the division occurs at the plexus, the common peronæal nerve usually pierces the Piriformis. The nerve also gives off articular and muscular branches.

In the upper part of its course the nerve rests upon the posterior surface of the ischium, the nerve to the Quadratus femoris, the Obturator internus and Gemelli, and the Quadratus femoris; it is accompanied on its medial side by the posterior femoral cutaneous nerve and the inferior glutæal artery, and is covered by the Glutæus maximus. Lower down, it lies upon the Adductor magnus, and is crossed obliquely by the long head of the Biceps femoris.

The *articular branches* of the sciatic nerve arise from the upper part of the nerve and supply the

* N.B.—In this diagram the medial sural cutaneous and peronæal anastomotic nerves have been displaced by the removal of the superficial muscles.

hip-joint, perforating the posterior part of its capsule; they are sometimes derived from the sacral plexus.

The *muscular branches* of the sciatic nerve are distributed to the Biceps femoris, Semitendinosus, Semimembranosus, and Adductor magnus. The nerve to the short head of the Biceps femoris comes from the common peronæal part, while the other muscular branches arise from the tibial portion, of the sciatic nerve, as may be seen in those cases where there is a high division of the nerve.

The **tibial nerve** (internal popliteal nerve) (fig. 927), the larger terminal branch of the sciatic nerve, arises from the ventral branches of the anterior divisions of the fourth and fifth lumbar and first, second, and third sacral nerves. It descends along the back of the thigh and through the middle of the popliteal fossa, to the lower part of the Popliteus muscle, whence it passes with the popliteal artery beneath the arch of the Soleus. It then runs along the back of the leg with the posterior tibial vessels to the interval between the medial malleolus and the heel, where it divides beneath the laciniate ligament into the medial and lateral plantar nerves. In the thigh it is overlapped by the hamstring muscles above, and then becomes more superficial, and lies lateral to, and some distance from, the popliteal vessels; opposite the knee-joint, it is superficial to these vessels, and then crosses to the medial side of the popliteal artery. In the leg it is covered in the upper part of its course by the superficial muscles of the calf; lower down by the skin and the superficial and deep fasciæ. It is placed on the deep muscles, and lies at first on the medial side of the posterior tibial artery, but soon crosses that vessel and descends on its lateral side as far as the ankle. In the lower part of the leg it runs parallel with the medial margin of the tendo calcaneus.

The branches of this nerve are; articular, muscular, medial sural cutaneous, medial calcaneal, medial and lateral plantar.

Articular branches, usually three in number, supply the knee-joint; one branch accompanies the superior, and another the inferior, medial genicular artery; the third branch runs with the middle genicular artery. Just above its point of bifurcation the tibial nerve gives an articular branch to the ankle-joint.

Muscular branches, four or five in number, arise from the nerve as it lies between the two heads of the Gastrocnemius muscle; they supply that muscle, as well as the Plantaris, Soleus, and Popliteus. The branch for the Popliteus turns round the lower border of that muscle, and is distributed to its deep surface. Lower down, muscular branches arise independently or by a common trunk and supply the Soleus, Tibialis posterior, Flexor digitorum longus, and Flexor hallucis longus; the branch to the last muscle accompanies the peronæal artery; that to the Soleus enters the deep surface of the muscle.

The *medial sural cutaneous nerve* (n. communicans tibialis) descends between the two heads of the Gastrocnemius, and, about the middle of the back of the leg, pierces the deep fascia, and unites with the peronæal anastomotic branch of the common peronæal nerve to form the sural nerve (fig. 925). The *sural nerve* (external saphenous nerve) passes downwards near the lateral margin of the tendo calcaneus, lying close to the small saphenous vein, to the interval between the lateral malleolus and the calcaneus; it supplies the skin of the lateral and posterior part of the lower one-third of the leg. It runs forwards below the lateral malleolus, and is continued as the *lateral dorsal cutaneous nerve* along the lateral side of the foot and little toe, communicating on the dorsum of the foot with the intermediate dorsal cutaneous nerve, a branch of the superficial peronæal nerve. In the leg, its branches communicate with those of the posterior femoral cutaneous nerve.

The *medial calcaneal branch* perforates the laciniate ligament, and supplies the skin of the heel and medial side of the sole of the foot.

The **medial plantar nerve** (fig. 928), the larger of the two terminal divisions of the tibial nerve, accompanies the medial plantar artery. From its origin under the laciniate ligament it passes under cover of the Abductor hallucis, and, appearing between this muscle and the Flexor digitorum brevis, gives off a proper digital nerve to the medial side of the great toe and finally divides opposite the bases of the metatarsal bones into three common digital nerves.

Branches.—*Cutaneous branches* pierce the plantar aponeurosis between the Abductor hallucis and the Flexor digitorum brevis and are distributed to the skin of the sole of the foot.

Muscular branches supply the Abductor hallucis, the Flexor digitorum brevis, the Flexor hallucis brevis, and the first Lumbricalis; those for the Abductor hallucis and Flexor digitorum brevis arise from the trunk of the nerve near its origin and enter the deep surfaces of the muscles; the branch for the Flexor hallucis brevis springs from the proper digital nerve to the medial side of the great toe, and that for the first Lumbricalis from the first common digital nerve.

Articular branches supply the articulations of the tarsus and metatarsus.

Fig. 928.—The plantar nerves of the right foot.

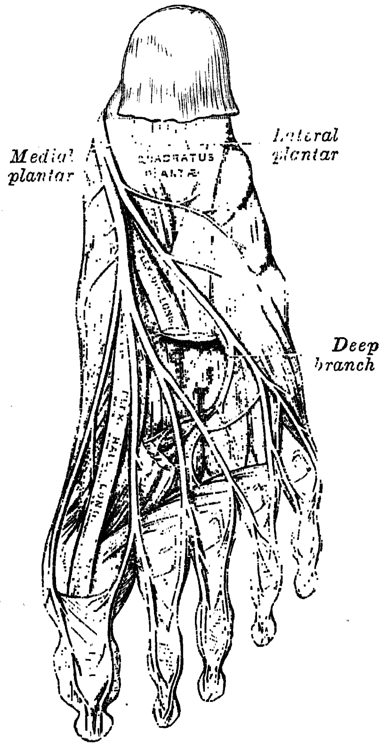
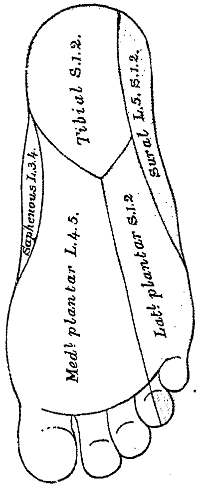


Fig. 929.—A diagram showing the segmental distribution of the cutaneous nerves of the sole of the right foot.



The *proper digital nerve of the great toe* supplies the Flexor hallucis brevis and the skin on the medial side of the great toe.

The *three common digital nerves* pass between the divisions of the plantar aponeurosis, and each splits into two proper digital nerves. Those of the first common digital nerve supply the adjacent sides of the great and second toes; those of the second, the adjacent sides of the second and third toes; and those of the third, the adjacent sides of the third and fourth toes. The third common digital nerve receives a communicating branch from the lateral plantar nerve; the first gives a twig to the first Lumbricalis. Each proper digital nerve gives off cutaneous and articular filaments, and opposite the last phalanx sends upwards a dorsal branch, which supplies the structures around the nail, the continuation of the nerve being distributed to the ball of the toe. It will be observed that the digital nerves of the medial plantar nerve are similar in their distribution to those of the median nerve in the hand.

The **lateral plantar nerve** (fig. 928) supplies the skin of the fifth toe and lateral half of the fourth, as well as most of the deep muscles, its distribution being similar to that of the ulnar nerve in the hand. It passes obliquely

forwards with the lateral plantar artery to the lateral side of the foot, lying between the Flexor digitorum brevis and Quadratus plantæ, and, in the interval between the former muscle and the Abductor digiti quinti, divides into a superficial and a deep branch. Before its division, it supplies the Quadratus plantæ and Abductor digiti quinti.

The *superficial branch* splits into a proper and a common digital nerve; the proper digital nerve supplies the lateral side of the little toe, the Flexor digiti quinti brevis, and the two Interossei of the fourth intermetatarsal space; the common digital nerve communicates with the third common digital branch of the medial plantar nerve and divides into two proper digital nerves which supply the adjoining sides of the fourth and fifth toes.

The *deep branch* accompanies the lateral plantar artery on the deep surface of the tendons of the flexor muscles and the Adductor hallucis, and supplies the second, third, and fourth Lumbricales, the Adductor hallucis, and all the Interossei (except those in the fourth metatarsal space).

The **common peronæal nerve** (external popliteal nerve) (fig. 927), about one-half the size of the tibial, is derived from the dorsal branches of the anterior divisions of the fourth and fifth lumbar and the first and second sacral nerves. It descends obliquely along the lateral side of the popliteal fossa to the head of the fibula, close to the medial margin of the Biceps femoris muscle. It lies between the tendon of the Biceps femoris and lateral head of the Gastrocnemius muscle, winds round the neck of the fibula, beneath the Peronæus longus, and divides under cover of that muscle into the superficial and deep peronæal nerves. Previous to its division it gives off articular and cutaneous branches.

The *articular branches* are three in number; two of these accompany the superior and inferior lateral genicular arteries to the knee; the upper one occasionally arises from the trunk of the sciatic nerve. The third, named the recurrent articular nerve, is given off at the point of division of the common peronæal nerve; it ascends with the anterior recurrent tibial artery through the Tibialis anterior to the front of the knee-joint.

The *cutaneous branches*, two in number, frequently spring from a common trunk; they are the lateral sural cutaneous and the peronæal anastomotic nerves.

The *lateral sural cutaneous nerve* supplies the skin on the anterior, posterior and lateral surfaces of the proximal part of the leg. The *peronæal anastomotic nerve* (n. communicans fibularis), arises near the head of the fibula, runs obliquely across the lateral head of the Gastrocnemius to the middle of the leg, and joins with the medial sural cutaneous to form the sural nerve (p. 963). The peronæal anastomotic nerve occasionally descends as a separate branch as far as the heel.

The **deep peronæal nerve** (anterior tibial nerve) (fig. 922) begins at the bifurcation of the common peronæal nerve, between the fibula and proximal part of the Peronæus longus, passes obliquely forwards beneath the Extensor digitorum longus to the front of the interosseous membrane, where it comes into relation with the anterior tibial artery in the upper one-third of the leg; it then descends with the artery to the front of the ankle-joint, where it divides into lateral and medial terminal branches. It lies at first on the lateral side of the anterior tibial artery, then in front of it, and again on its lateral side at the ankle-joint.

In the leg, the deep peronæal nerve supplies *muscular branches* to the Tibialis anterior, Extensor hallucis longus, Extensor digitorum longus and Peronæus tertius, and an *articular branch* to the ankle-joint.

The *lateral terminal branch* of the deep peronæal nerve passes across the tarsus, beneath the Extensor digitorum brevis, and, having become enlarged like the dorsal interosseous nerve at the wrist, supplies the Extensor digitorum brevis. From the enlargement three minute *interosseous branches* are given off, which supply the tarsal joints, and the metatarsophalangeal joints of the second, third, and fourth toes. The first of these sends a filament to the second Interosseus dorsalis muscle.

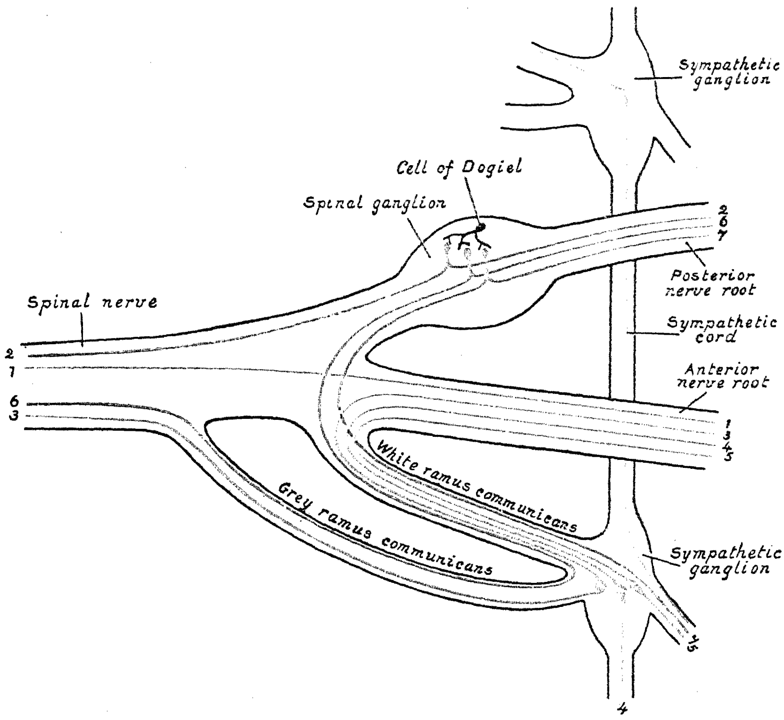
The *medial terminal branch* of the deep peronæal nerve runs forwards on the dorsum of the foot, on the lateral side of the dorsalis pedis artery. At the first interosseous space it communicates with the medial dorsal cutaneous branch of the superficial peronæal nerve, and divides into two dorsal digital nerves, which supply the adjacent sides of the great and second toes. Before it

part of the thoracic region, descend in contact with the medulla spinalis for a distance equal to the height of at least two vertebræ before they emerge from the vertebral canal.

The roots of the lower *lumbar* and upper *sacral* nerves are the largest, and their individual filaments the most numerous of all the spinal nerves, while the roots of the *coccygeal* nerve are the smallest.

The roots of the lumbar, sacral, and coccygeal nerves run vertically downwards to their respective exits, and as the medulla spinalis ends near the lower border of the first lumbar vertebra it follows that the lengths of the successive roots must rapidly increase. As already mentioned (p. 784), the term *cauda equina* is applied to this collection of nerve-roots.

FIG. 906.—A scheme showing the structure of a typical spinal nerve.



1. Somatic efferent. 2. Somatic afferent. 3, 4, 5. Autonomic efferent. 6, 7. Autonomic afferent.

From the description given it will be seen that the largest nerve-roots, and consequently the largest spinal nerves, are attached to the cervical and lumbar swellings of the medulla spinalis; these nerves are distributed to the upper and lower limbs.

Immediately beyond the spinal ganglion, the anterior and posterior nerve-roots unite to form the *spinal nerve* which emerges through the intervertebral foramen.

Connexions with the sympathetic trunks.—After emerging from the intervertebral foramen each spinal nerve receives a branch (*grey ramus communicans*) from the adjacent ganglion of the sympathetic trunk, while the thoracic, and the first and second lumbar nerves each contribute a branch (*white ramus communicans*) to the adjoining sympathetic ganglion. The second, third, and fourth sacral nerves also supply white rami; these, however, are not connected with the ganglia of the sympathetic trunk, but run directly into the pelvic plexuses.

Structure (figs. 905, 906).—Each typical spinal nerve contains fibres belonging to two systems, viz. the somatic, and the autonomic (p. 969), as well as fibres connecting these systems with one another.

towards the anal canal and the lower end of the rectum, and is distributed to the Sphincter ani externus and to the skin round the anus. Branches of this nerve communicate with the perinæal branch of the posterior femoral cutaneous and with the posterior scrotal nerves.

The *perinœal nerve*, the inferior and larger terminal branch of the pudendal nerve, is situated below the internal pudendal artery. It accompanies the perinæal artery and divides into posterior scrotal (or labial) and muscular branches.

The *posterior scrotal branches* (superficial perinæal nerves) are two, a medial and a lateral. They pierce, or pass superficial to, the fascia of the urogenital diaphragm, and run forwards along the lateral part of the urethral triangle in company with the posterior scrotal branches of the perinæal artery; they are distributed to the skin of the scrotum, and communicate with the perinæal branch of the posterior femoral cutaneous nerve. In the female the corresponding nerves (*posterior labial branches*) supply the labium majus.

The muscular branches are distributed to the Transversus perinæi superficialis, Bulbocavernosus, Ischiocavernosus, Transversus perinæi profundus, and Sphincter urethræ membranaceæ. A branch, the *nerve to the urethral bulb*, is given off from the nerve to the Bulbocavernosus; it pierces this muscle, and supplies the corpus cavernosum urethræ, ending in the mucous membrane of the urethra.

The *dorsal nerve of the penis* is the deepest division of the pudendal nerve; it accompanies the internal pudendal artery along the ramus of the ischium; it then runs forwards along the margin of the inferior ramus of the os pubis, between the superior and inferior layers of the fascia of the urogenital diaphragm. It pierces the inferior layer, and gives a branch to the corpus cavernosum penis. It then passes forwards, in company with the dorsal artery of the penis, between the layers of the suspensory ligament, to the dorsum of the penis, and ends on the glans penis. In the female the corresponding nerve (*dorsal nerve of the clitoris*) is very small, and supplies the clitoris.

The **visceral branches** arise from the second, third and fourth sacral nerves, and are distributed, through the pelvic plexuses of the sympathetic, to the bladder and rectum; in the female they also give branches to the vagina.

The **muscular branches** are derived from the fourth sacral, and supply the Levator ani, Coccygeus, and Sphincter ani externus. The branches to the Levator ani and Coccygeus enter their pelvic surfaces; that to the Sphincter ani externus (perinæal branch of fourth sacral nerve) reaches the ischiorectal fossa by piercing the Coccygeus or by passing between it and the Levator ani. Cutaneous filaments from this branch supply the skin between the anus and the coccyx.

The **anococcygeal nerves**.—The anterior division of the fifth sacral nerve receives a communicating filament from the fourth, and unites with the minute anterior division of the coccygeal nerve to form what is sometimes named the *coccygeal plexus*. The anococcygeal nerves arise from this plexus, and consist of a few fine filaments which pierce the sacrotuberous ligament and supply the skin in the region of the coccyx.

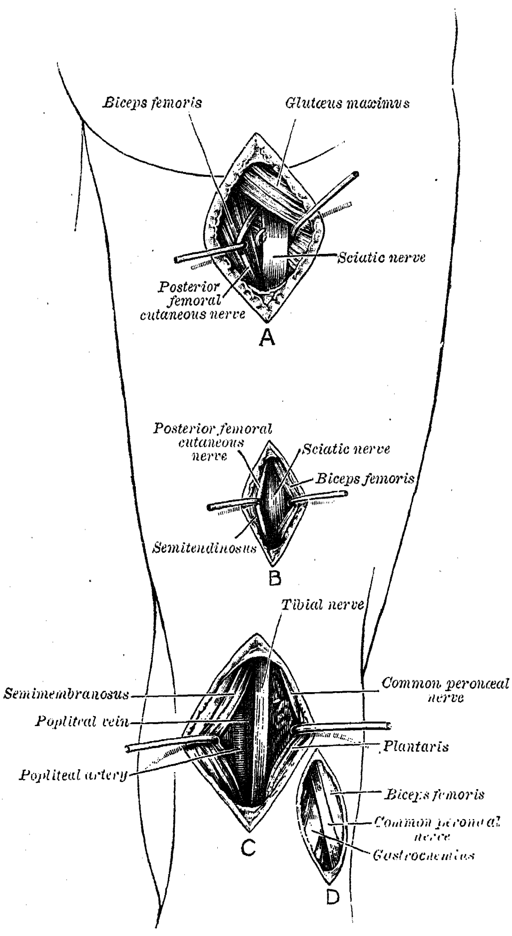
Applied Anatomy.—The lumbar plexus passes through the Psoas major, and therefore in psoas abscess any or all of its branches may be irritated, causing severe pain in the part to which the irritated nerves are distributed. The genitofemoral nerve is the one which is most frequently implicated. This nerve is also of importance as it is concerned in one of the principal superficial reflexes employed in the investigation of diseases of the medulla spinalis. If the skin over the medial side of the thigh just below the inguinal ligament (the part supplied by the lumbo-inguinal branch of the genitofemoral nerve) be tickled in the male child, the testis will be retracted, through the action of the Cremaster muscle which is supplied by the external spermatic branch of the genitofemoral nerve. The same result may sometimes be noticed in adults, and can almost always be produced by severe stimulation. This reflex shows that the portion of the medulla spinalis from which the first and second lumbar nerves are derived is in a normal condition.

The femoral nerve is in danger of being injured in fractures of the lesser pelvis, since the fracture most commonly takes place through the superior ramus of the os pubis, at or near the point where this nerve crosses the bone. It is also liable to be pressed upon and its functions impaired, by some tumours growing in the pelvis. Moreover, on account of its superficial position, it is exposed to injury in wounds and stabs in the groin. Its central origin is often affected in cases of infantile paralysis. When this nerve is paralysed, the patient is unable to flex his hip completely, on account of the paralysis of the Iliacus; or to extend the knee on the thigh, on account of paralysis of the Quadriceps

femoris; there is complete paralysis of the Sartorius, and partial paralysis of the Pectineus. There is loss of sensation down the front and medial side of the thigh, except in that part supplied by the lumbo-inguinal and ilio-inguinal nerves. There is also loss of sensation down the medial side of the leg and foot as far as the ball of the great toe.

The obturator nerve is rarely paralysed alone, but occasionally in association with the femoral. The principal interest attached to it is in connexion with its supply to the knee, pain in the knee being symptomatic of many diseases in which the trunk of this nerve, or one of its branches, is irritated. Thus it is well known that in the earlier stages of hip-joint disease the patient may not always complain of pain in that articulation, but on the medial side of the knee, or in the knee-joint itself, both of these articulations being supplied by the obturator nerve, the final distribution of the nerve being to the knee-joint. Again, the same thing may occur in sacro-iliac disease; or in cases of pathological growth of the ovary or tubal inflammation; or in cancer of the sigmoid colon; and even in cases where masses of hardened fæces are impacted in this portion of the gut, pain is complained of in the knee. Finally, pain in the knee forms an important diagnostic sign in obturator hernia. When the obturator nerve is paralysed the patient is unable to press his knees together or to cross one leg over the other on account of paralysis of the Adductor muscles. Rotation outwards of the thigh is impaired from paralysis of the Obturator externus. Sometimes there is loss of sensation in the upper half of the medial side of the leg.

Fig. 930.—Dissections to show (A, B) the sciatic nerve, (C) the upper part of the tibial nerve and (D) the common peronæal nerve.



The sciatic nerve is liable to be pressed upon by various forms of pelvic tumour, giving rise to pain along its trunk, to which the term *sciatica* is applied. Tumours growing from the pelvic viscera, especially advanced cancer of the rectum, aneurysms of some of the branches of the hypogastric artery, calculus in the bladder when of large size, accumulation of fæces in the rectum, may all cause pressure on the nerve inside the pelvis, and give rise to sciatica. Outside the pelvis, exostoses or other tumours growing from the margin of the greater sciatic foramen may also give rise to the same condition. Most cases of sciatica, however, are due to neuritis of the sciatic nerve from exposure to cold, and it occurs more often in men, in the latter half of life, and often in association with rheumatism, gout, or diabetes mellitus. The inflamed nerve is often sensitive to pressure, particularly in certain 'tender spots' (e.g. near the posterior iliac spine, at the sciatic notch about the middle of the back of the thigh, in the popliteal fossa, below the head of the fibula, behind the malleoli, or on the dorsum of the foot), and pain is felt whenever extension of the leg is attempted and the nerve is stretched. Paralysis of the sciatic nerve is rarely complete; when the lesion occurs high up there is palsy of the Biceps femoris, Semimembranosus, and Semitendinosus, and of all the muscles below the knee. If the lesion be lower down, there is loss of motion in all the muscles below the knee, and loss of sensation in the same situation, except the upper half of the back of the leg, which is supplied by the posterior femoral cutaneous, and in the upper half of the medial side of the leg, when the communicating branch of the obturator is large (p. 955). Lesions of the common peronæal nerve cause paralysis of the Tibialis anterior, the Peronæi, the long Extensors of the toes, and the short Extensor on the dorsum of the foot. 'Foot-drop' follows, dorsal flexion of the toes and abduction of the foot being impossible. Later on, talipes of the

equinovarus type results, due to the contracture of the unopposed posterior crural group of muscles.

The sciatic nerve has been frequently cut down upon and stretched, or has been acupunctured, for the relief of sciatica. In order to define it on the surface, a point is taken at the junction of the middle with the lower third of a line stretching from the posterior superior spine of the ilium to the lateral part of the ischial tuberosity, and a line drawn from this to the middle of the upper part of the popliteal fossa. The line must be slightly curved with its convexity outwards, and, as it passes downwards to the lower border of the Glutæus maximus, is slightly nearer to the ischial tuberosity than to the greater trochanter, as it crosses a line drawn between these two points. The operation of stretching the sciatic nerve is performed by making an incision over the course of the nerve beneath the fold of the buttock (fig. 930, A). The skin, superficial structures, and deep fascia having been divided, the hamstrings are defined, and pulled apart with retractors. The nerve will be found lying on the Adductor magnus and covered by the Biceps femoris. It is to be separated from the surrounding structures, hooked up with the finger, and stretched by steady and continuous traction for two or three minutes. The sciatic nerve may also be stretched by what is known as the 'dry' plan. The patient is laid on his back, the foot is extended, the leg flexed on the thigh, and the thigh strongly flexed on the abdomen. While the thigh is maintained in this position, the leg is forcibly extended to its full extent, and the foot as fully flexed on the leg.

The position of the common peronæal nerve, close behind the tendon of the Biceps femoris, on the lateral side of the popliteal fossa (fig. 930, D), should be remembered in subcutaneous division of the tendon. After the tendon is divided, the common peronæal nerve rises up as a cord, and might be mistaken for a small undivided portion of the tendon. Where this nerve winds round the neck of the fibula, it is also liable to be severed accidentally if its exact situation is not kept in mind, and especial care must be used when dealing with sinuses leading down to carious bone in this situation. Section of the nerve results in complete 'foot-drop' from paralysis of the anterior tibial group of muscles and inversion of the foot from the unopposed action of the Tibialis posterior, the Peronæi being paralysed, together with anæsthesia of the parts supplied by the nerve, and, owing to loss of nutrition, the limb frequently becomes blue and cold, and may develop 'trophic' sores.

THE AUTONOMIC NERVOUS SYSTEM

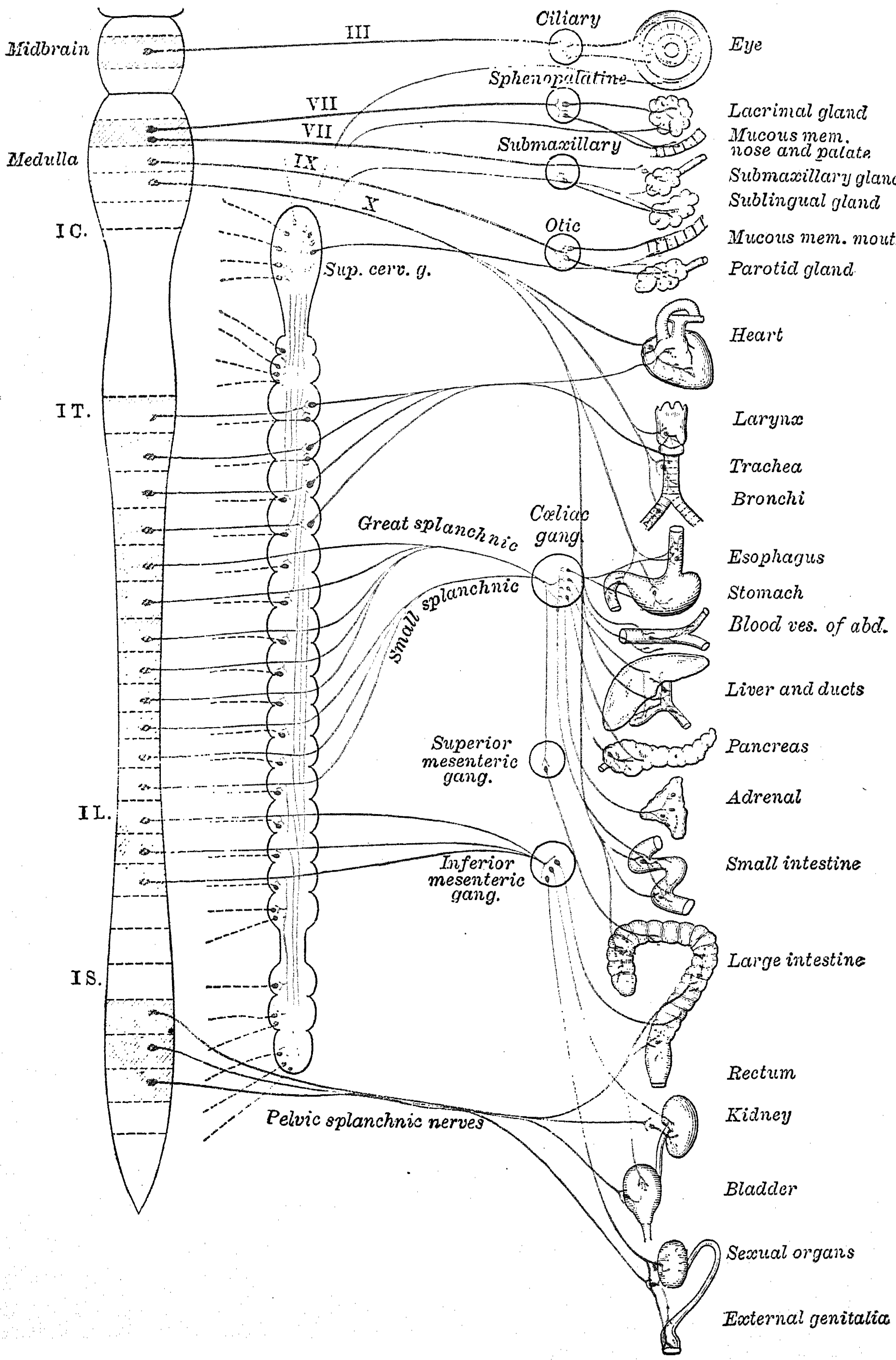
The autonomic nervous system (fig. 931) innervates the viscera, glands, blood-vessels, and unstriped muscle in general. Like the cerebrospinal system it has a central and a peripheral part. The central part is incorporated in the cerebrospinal axis and is represented by groups of nerve-cells, found chiefly in the mid-brain and hind-brain, and in the thoracic, lumbar, and sacral portions of the medulla spinalis. From these nerve-cells fibres pass out in certain of the cerebral and spinal nerves to form the peripheral part of the system. As already indicated (p. 779), none of these fibres reaches the zone of distribution of the autonomic system; all end round the cells of ganglia detached from the central nervous system, and from the cells of these ganglia the fibres of distribution are derived. The autonomic nerves, therefore, are composed of preganglionic and postganglionic fibres (p. 779).

The autonomic system is divisible into two secondary systems, (*a*) parasympathetic, and (*b*) sympathetic.

The **parasympathetic system** is found at the cranial and sacral ends of the autonomic system. The *cranial* parasympathetic fibres issue from the oculomotor, facial, glossopharyngeal, vagus, and accessory cerebral nerves. Those from the oculomotor and facial nerves, and some from the glossopharyngeal, run to the ciliary, sphenopalatine, otic and submaxillary ganglia, and have been described with the trigeminal nerve (pp. 892 to 903). The fibres of the glossopharyngeal, vagus and accessory nerves are largely parasympathetic; their distribution is described on pp. 915 to 922; the ganglia with which they are associated lie mainly at the periphery, i.e. in the walls of the structures they innervate. The *sacral* parasympathetic fibres emerge in the second, third and fourth sacral nerves and constitute the *pelvic splanchnic nerves* of Gaskell. They end in ganglia in the pelvic plexuses, and from the cells of these ganglia postganglionic fibres are distributed to the viscera of the pelvis.

The **sympathetic system** forms the remaining and greater part of the autonomic system. It is associated with the thoracic and lumbar parts of the medulla spinalis, and its efferent fibres emerge in the thoracic, and the first

FIG. 931.—A diagram of the autonomic nervous system. (After Meyer and Gottlieb.) The parasympathetic fibres are represented by *blue*, and the sympathetic fibres by *red*, lines; the interrupted red lines indicate postganglionic fibres to the cerebral and spinal nerves.



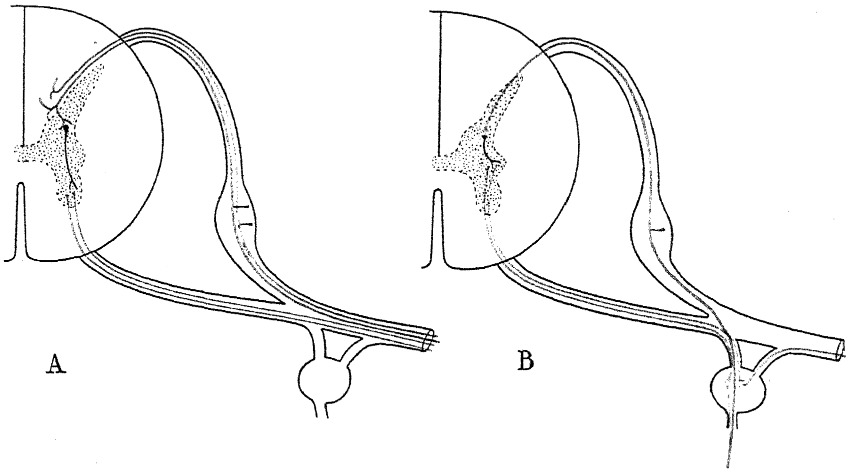
and second lumbar, nerves ; leaving these nerves through the white rami communicantes, they run to join sympathetic ganglia. The sympathetic system, with its associated ganglia forms a complex widespread system, the communications and distribution of which are described in the following pages.

Accompanying the autonomic nerves are afferent fibres, which originate in the cells of the semilunar ganglion of the trigeminal, the genicular ganglion of the facial, the ganglia on the trunks of the glossopharyngeal and vagus nerves, and the ganglia of the spinal nerves. The peripheral branches of these fibres pass without interruption to the involuntary structures; the central branches pass into the brain and medulla spinalis to complete autonomic reflex arcs, or to form synapses with the somatic nerve-cells.

THE SYMPATHETIC NERVOUS SYSTEM

The ganglia associated with the sympathetic system may be divided into central, collateral and terminal groups. The *central* ganglia are arranged in two vertical rows, one on either side of the middle line, and situated partly

Fig. 932.—Sketches showing the central connexions of the somatic fibres (A) and sympathetic fibres (B) of a typical spinal nerve. The efferent fibres are represented by *red*, and the afferent fibres by *blue*, lines.



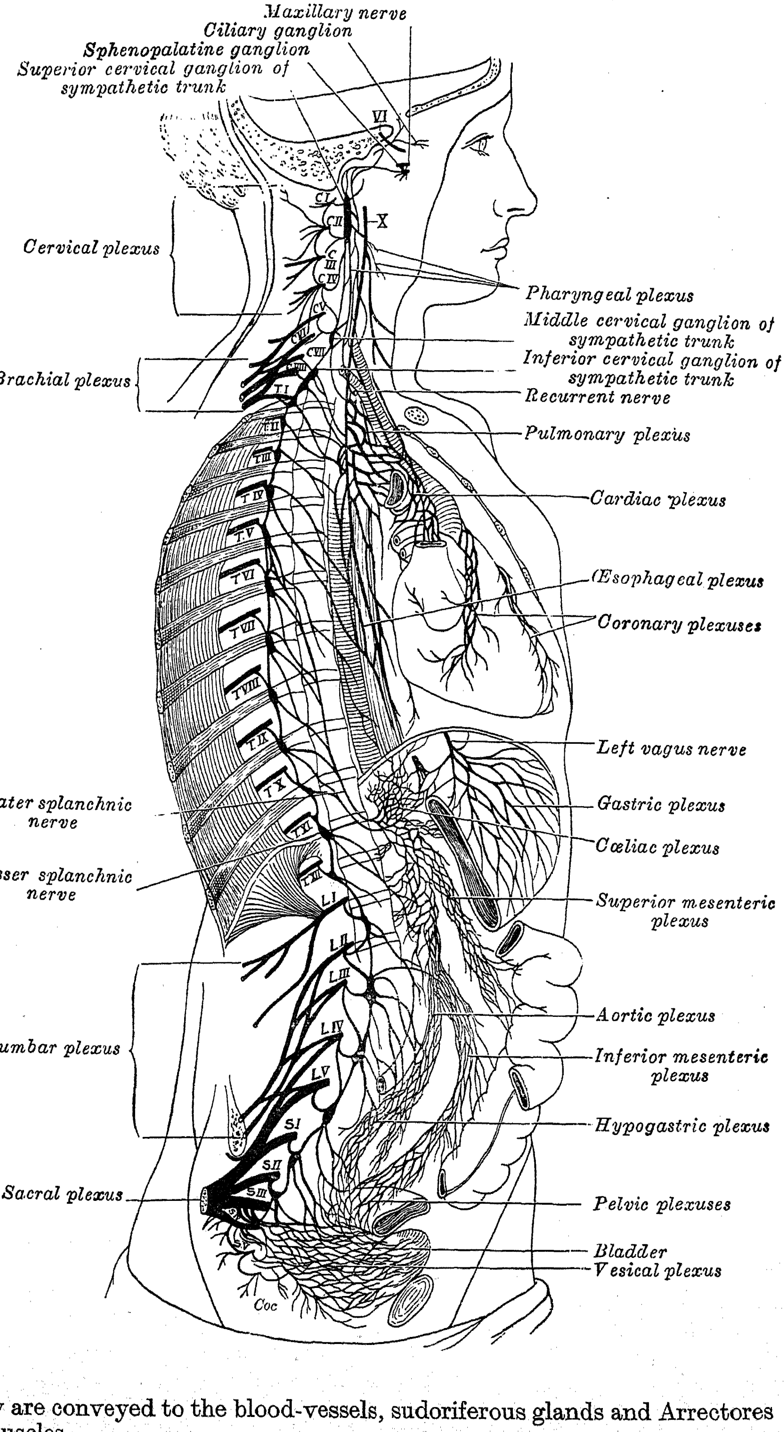
in front, and partly at the sides, of the vertebral column. In both rows the successive ganglia are connected to one another by nervous cords, so that two chains or trunks, named the *sympathetic trunks*, are formed. The *collateral* ganglia are found in connexion with three great *prevertebral plexuses* situated within the thorax, abdomen and pelvis, and named the cardiac, cœliac, and hypogastric plexuses. The *terminal* ganglia are located in the walls of the viscera.

The efferent fibres of the sympathetic nerves are the axons of nerve-cells in the lateral grey column of the medulla spinalis (fig. 932). These fibres, medullated, and mostly of small size, issue from the medulla spinalis through the anterior nerve-roots of the thoracic and first and second lumbar nerves. They leave these nerves as the white rami communicantes (p. 927), each of which joins a neighbouring ganglion of the sympathetic trunk. Some of the fibres end in the ganglion which they first enter ; others pass through that ganglion and end in a collateral or a terminal ganglion ; others run in the sympathetic trunk and end in higher or lower ganglia in the trunk, while others, after ascending or descending for varying distances, leave the trunk and end around the cells of collateral or terminal ganglia.

Fibres, mostly non-medullated, arise from the cells of the sympathetic ganglia. Some of these fibres go directly, or through the prevertebral plexuses,

to their distribution in the viscera; others leave the sympathetic trunks in the grey rami communicantes (p. 927) and join the spinal nerves, through

FIG. 933.—The right sympathetic trunk and its connexions with the thoracic, abdominal, and pelvic plexuses. (After Schwalbe.)



which they are conveyed to the blood-vessels, sudoriferous glands and Arrectores pilorum muscles.

The **sympathetic trunks** (fig. 933) extend from the base of the skull to the coccyx. Each trunk is continued upwards, under the name of the internal carotid nerve, through the carotid canal into the skull. Here it forms the carotid and cavernous plexuses which constitute the *cephalic part* of the sympathetic system. The lower ends of the sympathetic trunks converge and unite in a single ganglion, the *ganglion impar*, which is placed in front of the coccyx. The ganglia of each trunk are distinguished as cervical, thoracic, lumbar, and sacral, and, except in the neck, their number corresponds more or less closely to that of the spinal nerves. They are arranged thus:

Cervical portion	3	ganglia
Thoracic ,,	12	,,
Abdominal ,,	4	,,
Pelvic ,,	4 or 5	,,

In the neck the ganglia lie in front of the transverse processes of the vertebræ; in the thoracic region in front of the heads of the ribs; in the abdomen on the sides of the vertebral bodies; and in the pelvis in front of the sacrum.

The Cephalic Portion of the Sympathetic System

The **cephalic portion** of the sympathetic system on each side begins as the **internal carotid nerve**, which is continued upwards from the superior cervical ganglion of the sympathetic trunk. This nerve is soft in texture, and of a reddish colour. It ascends by the side of the internal carotid artery, and, entering the carotid canal in the temporal bone, divides into two branches, one of which lies on the lateral and the other on the medial side of the artery.

The *lateral branch*, the larger of the two, gives filaments to the internal carotid artery, and forms the *internal carotid plexus*.

The *medial branch* also supplies filaments to the internal carotid artery, and, continuing onwards, forms the *cavernous plexus*.

The **internal carotid plexus** is situated on the lateral side of the internal carotid artery, and in the plexus there occasionally exists a small gangliform swelling, the *carotid ganglion*, on the under surface of the artery. The plexus communicates with the semilunar and sphenopalatine ganglia, and with the abducent nerve and the tympanic branch of the glossopharyngeal nerve; it distributes filaments to the wall of the carotid artery.

The branches communicating with the abducent nerve consist of one or two filaments which join that nerve as it lies upon the lateral side of the internal carotid artery. The communication with the sphenopalatine ganglion is effected by a branch named the *deep petrosal*; this branch perforates the cartilage filling the foramen lacerum, and joins the greater superficial petrosal nerve to form the nerve of the pterygoid canal (Vidian nerve), which passes through the pterygoid canal to the sphenopalatine ganglion. The communication with the tympanic branch of the glossopharyngeal nerve is effected by the *superior* and *inferior caroticotympanic nerves* which traverse the wall of the carotid canal.

The **cavernous plexus**, formed chiefly by the medial division of the internal carotid nerve, is situated below and on the medial side of that part of the internal carotid artery which is placed by the side of the sella turcica, in the cavernous sinus. It gives branches to the internal carotid artery, and communicates with the oculomotor, trochlear, ophthalmic, and abducent nerves, and with the ciliary ganglion.

The branch to the oculomotor nerve joins that nerve at its point of division; the branch to the trochlear nerve joins the latter as it lies in the lateral wall of the cavernous sinus; filaments are connected with the medial side of the ophthalmic nerve; and one joins the abducent nerve. The filament to the ciliary ganglion arises from the anterior part of the cavernous plexus and enters the orbit through the superior orbital fissure; it may join the ganglion directly, or may unite with the long root of the ganglion.

The terminal filaments from the internal carotid and cavernous plexuses are prolonged as plexuses around the anterior and middle cerebral arteries

and the ophthalmic artery: along the anterior and middle cerebral arteries they may be traced to the pia mater; along the ophthalmic artery they pass into the orbit where they accompany each of the branches of that vessel. The filaments prolonged on the anterior communicating artery connect the sympathetic nerves of the right and left sides.

The Cervical Portion of the Sympathetic System

The **cervical portion** of each sympathetic trunk consists of three ganglia distinguished, according to their positions, as the superior, middle, and inferior, and connected by intervening cords. This portion receives no white rami communicantes from the cervical spinal nerves; its spinal fibres are derived from the white rami communicantes of the upper thoracic nerves, and enter the corresponding thoracic ganglia of the sympathetic trunk, through which they ascend into the cervical ganglia.

The **superior cervical ganglion**, the largest of the three, is placed opposite the second and third cervical vertebræ. It is of a reddish-grey colour and usually fusiform in shape, sometimes broad and flattened, and occasionally constricted at intervals; it is believed to be formed by the coalescence of four ganglia, corresponding with the upper four cervical nerves. It is in relation, in front, with the sheath of the internal carotid artery and internal jugular vein; behind, with the Longus capitis muscle. The internal carotid nerve (p. 973) ascends from the upper end of the ganglion into the cranial cavity; the lower end of the ganglion is united by the connecting trunk with the middle cervical ganglion.

Its branches may be divided into lateral, medial, and anterior.

The **lateral branches** of the superior cervical ganglion consist of grey rami communicantes to the upper four cervical nerves and to certain of the cerebral nerves. Sometimes the branch to the fourth cervical nerve comes from the trunk connecting the superior and middle cervical ganglia. Delicate filaments run to the ganglion nodosum of the vagus, and to the hypoglossal nerve; and a branch, named the *jugular nerve*, ascends to the base of the skull, and divides into two twigs, one of which joins the petrous ganglion of the glossopharyngeal, and the other the jugular ganglion of the vagus.

The **medial branches** of the superior cervical ganglion are the laryngopharyngeal branches and the superior cardiac nerve.

The *laryngopharyngeal branches* pass to the side of the pharynx, where they join with branches from the glossopharyngeal and vagus nerves to form the *pharyngeal plexus*. From this plexus branches pass to the muscles and mucous membrane of the pharynx, and communicate with the superior laryngeal nerve.

The *superior cardiac nerve* arises by two or more branches from the superior cervical ganglion, and occasionally receives a filament from the trunk connecting the superior with the middle cervical ganglion. It runs down the neck behind the common carotid artery, and in front of the Longus colli muscle; and crosses in front of the inferior thyreoid artery, and recurrent nerve. The course of the nerve of the right side then differs from that of the left. The *right nerve*, at the root of the neck, passes either in front of or behind the subclavian artery, and along the innominate artery to the back of the arch of the aorta, where it joins the deep part of the cardiac plexus. It is connected with other branches of the sympathetic; about the middle of the neck it receives filaments from the external laryngeal nerve; lower down, one or two twigs (upper cervical branches) from the vagus nerve join it; and as it enters the thorax it is joined by a filament from the recurrent nerve. Filaments from the nerve communicate with the thyreoid branches from the middle cervical ganglion. The *left nerve*, in the thorax, runs in front of the left common carotid artery and across the left side of the arch of the aorta, to the superficial part of the cardiac plexus. Sometimes it descends on the right side of the aorta and ends in the deep part of the cardiac plexus.

The **anterior branches** of the superior cervical ganglion ramify upon the common carotid artery, and upon the external carotid artery and its branches, forming around each a delicate plexus in which small ganglia are occasionally found. The plexus surrounding the external maxillary artery supplies a

filament to the submaxillary ganglion, and the plexus on the middle meningeal artery sends one offset to the otic ganglion, and another, the *external petrosal nerve*, to the genicular ganglion.

The **middle cervical ganglion,** the smallest of the three cervical ganglia, is occasionally wanting. It is placed opposite the sixth cervical vertebra, usually in front of, or close to, the inferior thyreoid artery. It is probably formed by the coalescence of two ganglia corresponding with the fifth and sixth cervical nerves.

The ganglion sends grey rami communicantes to the fifth and sixth cervical nerves, and gives off thyreoid branches, and the middle cardiac nerve. It is connected to the inferior cervical ganglion by two or more cords, one of which forms a loop around the subclavian artery, and supplies offsets to it. This loop is named the *ansa subclavia* (*Vieussenii*).

The *thyreoid branches* run along the inferior thyreoid artery to the thyreoid gland; they communicate with the superior cardiac, external laryngeal and recurrent nerves.

The *middle cardiac nerve*, the largest of the three cardiac nerves, arises from the middle cervical ganglion, or from the trunk connecting the middle with the inferior cervical ganglion. On the *right side* it descends behind the common carotid artery, and at the root of the neck runs either in front of or behind the subclavian artery; it then descends on the trachea, receives a few filaments from the recurrent nerve, and joins the right half of the deep part of the cardiac plexus. In the neck, it communicates with the superior cardiac and recurrent nerves. On the *left side*, the middle cardiac nerve enters the thorax between the left carotid and subclavian arteries, and joins the left half of the deep part of the cardiac plexus.

The **inferior cervical ganglion** is situated between the base of the transverse process of the last cervical vertebra and the neck of the first rib, on the medial side of the costocervical trunk. Its form is irregular; it is larger than the middle cervical ganglion, and is frequently fused with the first thoracic ganglion. It is probably formed by the coalescence of two ganglia corresponding with the seventh and eighth cervical nerves.

The ganglion sends grey rami communicantes to the seventh and eighth cervical nerves, gives off the inferior cardiac nerve, and supplies branches to blood-vessels.

The *inferior cardiac nerve* arises from either the inferior cervical or the first thoracic ganglion. It descends behind the subclavian artery and along the front of the trachea, to join the deep part of the cardiac plexus. Behind the subclavian artery it communicates with the recurrent nerve and the middle cardiac nerve.

The *offsets to blood-vessels* form plexuses on the subclavian artery and its branches. The plexus on the vertebral artery is continued on the basilar, posterior cerebral, and cerebellar arteries. The plexus on the inferior thyreoid artery accompanies the artery to the thyreoid gland, and communicates with the recurrent and external laryngeal nerves, with the superior cardiac nerve, and with the plexus on the common carotid artery.

The Thoracic Portion of the Sympathetic System (fig. 934)

The **thoracic portion** of the sympathetic trunk consists on either side of a series of ganglia, which usually correspond in number to that of the thoracic spinal nerves; but, on account of the occasional coalescence of two ganglia, their number is variable. The thoracic ganglia, with the exception of the last two, rest against the heads of the ribs, and are covered by the costal pleura; the last two are placed on the sides of the bodies of the eleventh and twelfth thoracic vertebræ. The ganglia are small, and of a greyish colour, and are connected together by the intervening portions of the trunk. The first is larger than the others, and of an elongated form; it is frequently blended with the inferior cervical ganglion.

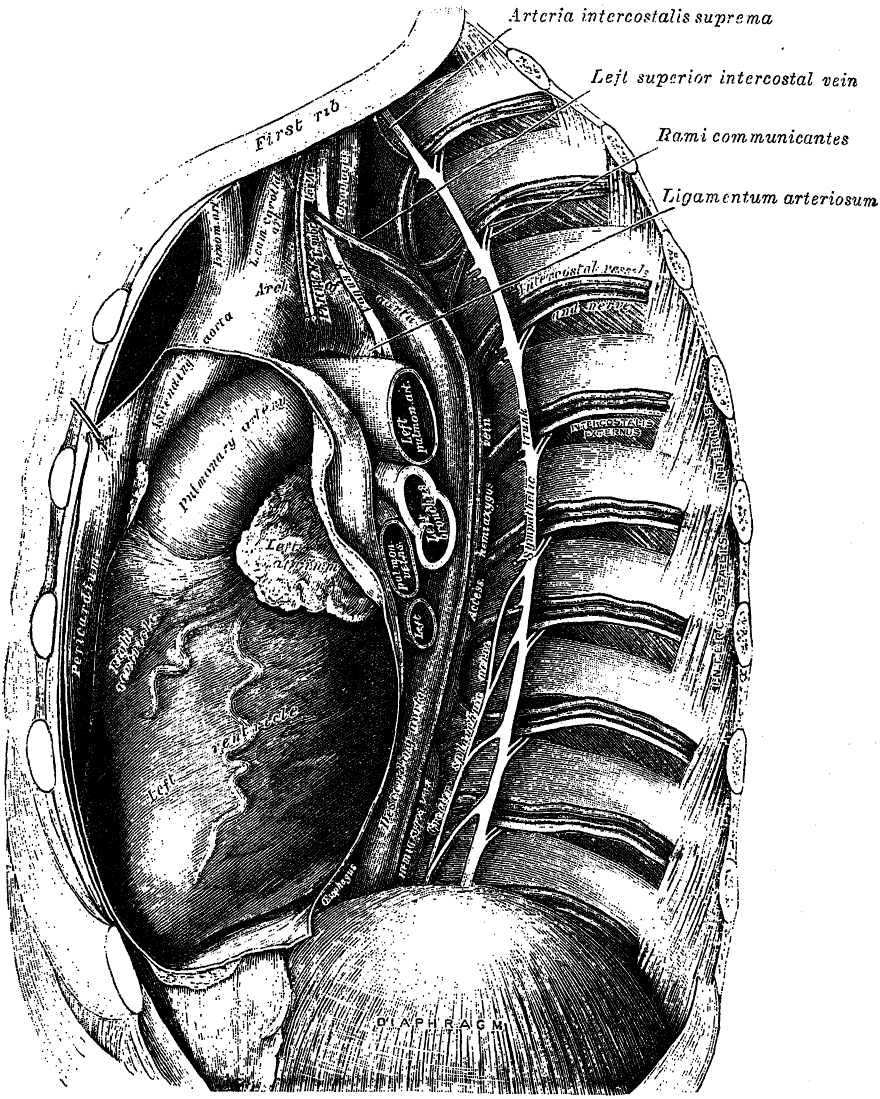
Two rami communicantes, a white and a grey, connect each ganglion with its corresponding spinal nerve.

The *branches from the upper five ganglia* are very small; they supply filaments to the thoracic aorta and its branches. On the aorta they form, together

with filaments from the greater splanchnic nerve, a delicate plexus (*plexus aorticus thoracalis*). Twigs from the second, third, and fourth ganglia enter the posterior pulmonary plexus.

The *branches from the lower seven ganglia* are large, and white in colour; they distribute filaments to the aorta, and unite to form the greater, the lesser, and the lowest splanchnic nerves.

FIG. 934.—The thoracic portion of the left sympathetic trunk.



The *greater splanchnic nerve* is of a considerable size, and consists mainly of medullated fibres; it is formed by branches from the fifth to the ninth or tenth thoracic ganglia, but the fibres in the higher branches may be traced upwards in the sympathetic trunk as far as the first or second thoracic ganglion. It descends obliquely on the bodies of the vertebræ, perforates the crus of the Diaphragm, and ends in the cœliac ganglion. A ganglion (*ganglion splanchnicum*) exists on this nerve opposite the eleventh or twelfth thoracic vertebra.

The *lesser splanchnic nerve* is formed by filaments from the ninth and tenth, sometimes the tenth and eleventh, thoracic ganglia, and from the trunk between

the ganglia. It pierces the Diaphragm with the preceding nerve, and joins the aorticorenal ganglion.

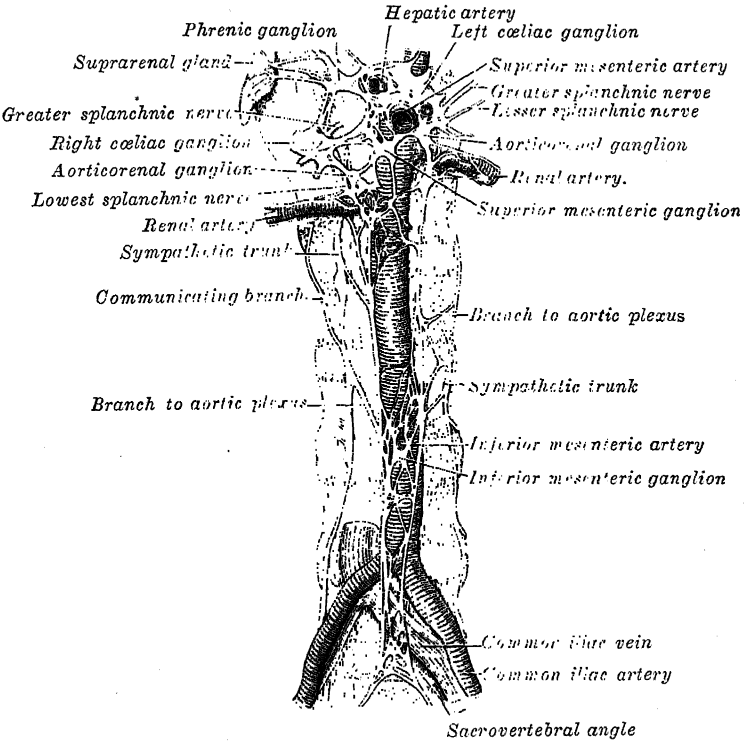
The *lowest splanchnic nerve* arises from the last thoracic ganglion. It pierces the Diaphragm with the sympathetic trunk, and ends in the renal plexus.

A striking analogy exists between the splanchnic and the cardiac nerves. The cardiac nerves, three in number, arise from the cervical ganglia, and are distributed to a large and important organ in the thoracic cavity. The splanchnic nerves, also three in number, arise from the thoracic ganglia, and are distributed to organs in the abdominal cavity.

THE ABDOMINAL PORTION OF THE SYMPATHETIC SYSTEM (fig. 935)

The **abdominal portion** of each sympathetic trunk is situated in front of the vertebral column, along the medial margin of the Psoas major. It consists usually

FIG. 935.—The abdominal portion of the sympathetic trunks, with the cœliac and aortic plexuses. (After Henle.)



of four lumbar ganglia, connected together by the intervening portions of the trunk. It is continuous above with the thoracic portion, beneath the medial lumbocostal arch; below with the pelvic portion, behind the common iliac artery.

Grey rami communicantes pass from all the ganglia to the lumbar spinal nerves. The first and second, and sometimes the third, lumbar nerves send white rami communicantes to the corresponding ganglia. The rami communicantes are of considerable length, and accompany the lumbar arteries around the sides of the bodies of the vertebræ, beneath the fibrous arches which give origin to some of the fibres of the Psoas major.

Of the *branches of distribution*, some pass in front of the aorta, and join the abdominal aortic plexus; others descend in front of the common iliac arteries, and assist in forming the hypogastric plexus.

The Pelvic Portion of the Sympathetic System (fig. 933)

The **pelvic portion** of each sympathetic trunk is situated in front of the sacrum, medial to the anterior sacral foramina. It consists of four or five small sacral ganglia, connected by the intervening portions of the trunk. It is continuous above with the abdominal portion, while below, the two pelvic sympathetic trunks converge, and unite on the front of the coccyx in a small ganglion, the *ganglion impar* or *coccygeal ganglion.*

Grey rami communicantes pass from the ganglia to the sacral and coccygeal nerves. No white rami communicantes pass to this part of the sympathetic trunk, but the visceral branches (*pelvic splanchnic nerves of Gaskell*) which arise from the second, third and fourth sacral nerves (p. 969), and run through the pelvic plexuses of the sympathetic, are regarded as white rami communicantes.

The *branches of distribution* communicate on the front of the sacrum with the corresponding branches from the opposite side; twigs from the first two ganglia join the pelvic plexuses, and others form a plexus on the middle sacral artery. Filaments are distributed to the glomus coccygeum (coccygeal body) from the loop uniting the two trunks.

The following facts concerning the course of the sympathetic nerve-fibres have been arrived at by experiments on lower animals, chiefly dogs, but they probably hold good for the human sympathetic system :—

The preganglionic sympathetic fibres for the head and neck leave the medulla spinalis through the upper five thoracic nerves (chiefly through the second and third nerves). They ascend in the cervical part of the sympathetic trunk and end in the superior cervical ganglion. The fibres arising from the cells of this ganglion are vasoconstrictor for the blood-vessels, secretory for the salivary and sudoriferous glands, and dilator for the pupil.

The accelerator fibres of the heart leave mainly through the second and third thoracic nerves and pass to the *stellate* ganglion.* From the cells of this ganglion and of the inferior cervical ganglion, fibres are distributed to the heart.

Fibres leave the thoracic spinal nerves (mainly the lower six) and are conveyed through the splanchnic nerves to the cœliac ganglion, from the cells of which fibres pass to the blood-vessels and viscera of the abdominal cavity. Fibres from the lower thoracic and upper three or four lumbar nerves pass through the ganglia of the lumbar part of the sympathetic trunk to the inferior mesenteric ganglion ; from this ganglion fibres are conveyed through the hypogastric and pelvic plexuses to the pelvic viscera.

No spinal fibres pass from the sacral nerves to the sympathetic trunks, but the visceral branches of the second, third and fourth sacral nerves correspond to white rami communicantes and enter the pelvic sympathetic plexuses. From these plexuses fibres are conveyed to the pelvic viscera, and vasodilator fibres (nervi erigentes) to the penis.

The constrictor fibres for the blood-vessels of the upper limbs leave the thoracic nerves from about the fourth to the tenth inclusive; those for the lower limbs through the lower two or three thoracic and upper three lumbar nerves; the former have their "cell-station" in the stellate ganglion, the latter in the sixth and seventh lumbar and first sacral ganglia.

THE GREAT PLEXUSES OF THE SYMPATHETIC

The great plexuses of the sympathetic are aggregations of nerves and ganglia, situated in the thoracic, abdominal, and pelvic cavities, and named the cardiac, cœliac, and hypogastric plexuses. They consist not only of sympathetic fibres derived from the ganglia, but of fibres from the medulla spinalis, which are conveyed through the white rami communicantes. From the plexuses branches are given to the thoracic, abdominal, and pelvic viscera.

The Cardiac Plexus (fig. 933)

The **cardiac plexus** is situated at the base of the heart, and is divided into a *superficial* and a *deep part,* which are, however, closely connected.

The **superficial part of the cardiac plexus** lies beneath the arch of the aorta, in front of the right pulmonary artery. It is formed by the superior

* In the dog the upper four thoracic ganglia of the sympathetic trunk are fused into one mass which is named the *stellate* ganglion.

cardiac branch of the left sympathetic trunk and the lower of the superior cardiac branches of the left vagus. A small ganglion, the *cardiac ganglion of Wrisberg*, is usually found in this plexus, and is situated immediately beneath the arch of the aorta, on the right side of the ligamentum arteriosum. The superficial part of the cardiac plexus gives branches (*a*) to the deep part of the plexus; (*b*) to the anterior coronary plexus; and (*c*) to the left anterior pulmonary plexus.

The **deep part of the cardiac plexus** is situated in front of the bifurcation of the trachea, above the point of division of the pulmonary artery, and behind the aortic arch. It is formed by the cardiac nerves derived from the cervical ganglia of the sympathetic trunk, and the cardiac branches of the vagus and recurrent nerves. The only cardiac nerves which do not join the deep part of the cardiac plexus are the superior cardiac nerve of the left sympathetic trunk, and the lower of the superior cardiac branches from the left vagus nerve, which pass to the superficial part of the plexus.

The branches from the *right half* of the deep part of the cardiac plexus pass, some in front of, and others behind, the right pulmonary artery; the former, the more numerous, transmit a few filaments to the anterior pulmonary plexus, and are then continued onwards to form part of the anterior coronary plexus; those behind the pulmonary artery distribute a few filaments to the right atrium, and are then continued onwards to form part of the posterior coronary plexus.

The *left half* of the deep part of the cardiac plexus is connected with the superficial part of the plexus, and gives filaments to the left atrium, and to the anterior pulmonary plexus, and is then continued to form the greater part of the posterior coronary plexus.

The **posterior coronary plexus** is larger than the anterior, and accompanies the left coronary artery; it is formed chiefly by filaments prolonged from the left half of the deep part of the cardiac plexus, and by a few from the right half. It gives branches to the left atrium and ventricle.

The **anterior coronary plexus** is formed partly from the superficial and partly from the deep parts of the cardiac plexus. It accompanies the right coronary artery, and gives branches to the right atrium and ventricle.

The upper cardiac nerves are distributed to the ascending aorta, the pulmonary artery and the ventricles; the lower cardiac nerves, to the atria.

THE CŒLIAC PLEXUS (figs. 933, 935, 936)

The **cœliac or solar plexus**, the largest of the three great sympathetic plexuses, is situated at the level of the upper part of the first lumbar vertebra, and is composed of a pair of large ganglia, the cœliac ganglia, and a dense network of nerve-fibres uniting them together. It surrounds the cœliac artery and the root of the superior mesenteric artery. It lies behind the stomach and the omental bursa, in front of the crura of the Diaphragm and the commencement of the abdominal aorta, and between the suprarenal glands. The plexus and the ganglia receive the greater and lesser splanchnic nerves of both sides and some filaments from the right vagus, and give off numerous secondary plexuses along the neighbouring arteries.

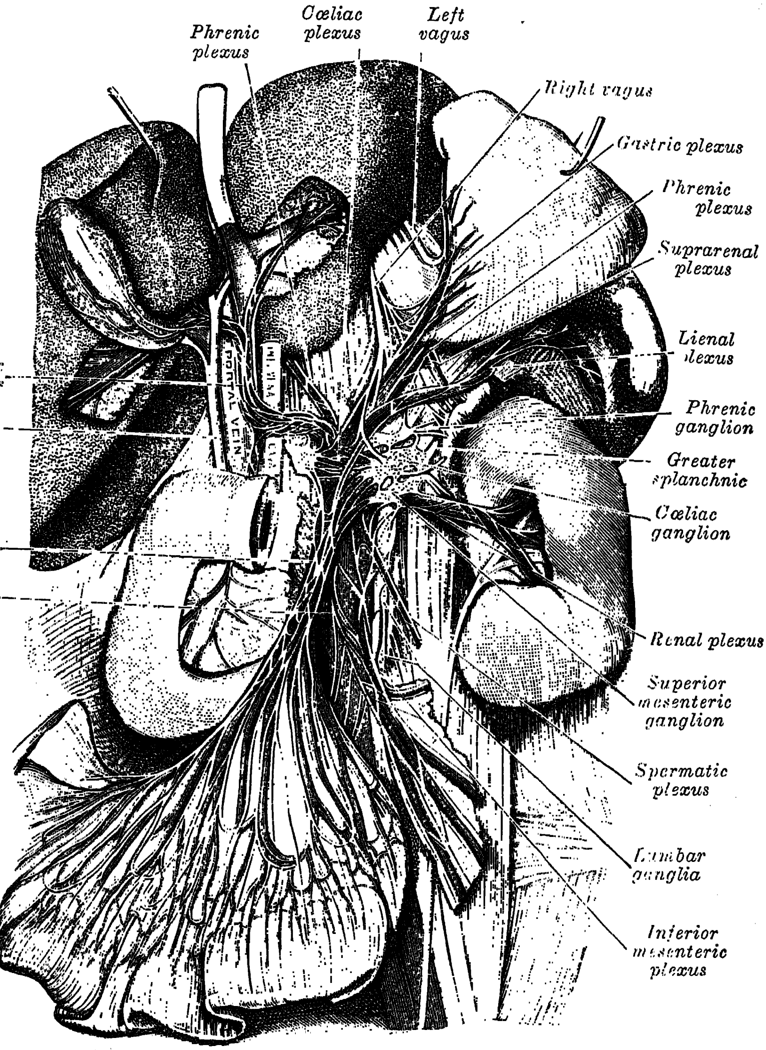
The *cœliac or semilunar ganglia* are two large irregularly-shaped masses having the appearance of lymph-glands, and placed, one on either side of the middle line, in front of the crura of the Diaphragm close to the suprarenal glands, that on the right side being placed behind the inferior vena cava. The upper part of each ganglion is joined by the greater splanchnic nerve, while the lower part, which is more or less detached, and named the *aorticorenal* ganglion, receives the lesser splanchnic nerve and gives off the greater part of the renal plexus.

The secondary plexuses springing from or connected with the cœliac plexus are the following:

Phrenic.	Renal.
Hepatic.	Spermatic.
Lienal.	Superior mesenteric.
Superior gastric.	Abdominal aortic.
Suprarenal.	Inferior mesenteric.

The **phrenic plexus** accompanies the inferior phrenic artery to the Diaphragm, some filaments passing to the suprarenal gland. It arises from the upper part of the cœliac ganglion, and is larger on the right than on the left side. It receives one or two branches from the phrenic nerve. At the point of junction of the right phrenic plexus with the phrenic nerve is a small ganglion (*ganglion phrenicum*). This plexus distributes some branches to the inferior vena cava, and to the suprarenal and hepatic plexuses.

FIG. 936.—The cœliac ganglia with the sympathetic plexuses of the abdominal viscera radiating from the ganglia. (From Toldt's 'Atlas,' published by Messrs. Rebman, Ltd., London.)



The **hepatic plexus**, the largest offset from the cœliac plexus, receives filaments from the left vagus and right phrenic nerves. It accompanies the hepatic artery, ramifying upon its branches, and upon those of the portal vein, in the substance of the liver. Branches from this plexus accompany all the branches of the hepatic artery. A considerable plexus accompanies the gastroduodenal artery and is continued as the *inferior gastric plexus* on the right gastro-epiploic artery along the greater curvature of the stomach, where it unites with offshoots from the lienal plexus.

The **lienal or splenic plexus** is formed by branches from the cœliac

plexus, left cœliac ganglion, and right vagus nerve. It accompanies the lienal artery to the spleen, giving off, in its course, subsidiary plexuses along the various branches of the artery.

The **superior gastric plexus** accompanies the left gastric artery along the lesser curvature of the stomach, and joins with branches from the left vagus.

The **suprarenal plexus** is formed by branches from the cœliac plexus, from the cœliac ganglion, and from the phrenic and greater splanchnic nerves, a ganglion being formed at the point of junction with the latter nerve. The plexus supplies the suprarenal gland, and is distributed chiefly to its medullary portion; its branches are remarkable for their large size in comparison with that of the organ they supply.

The **renal plexus** is formed by filaments from the cœliac plexus, the aorticorenal ganglion, and the aortic plexus. It is joined also by the smallest splanchnic nerve. The nerves from these sources, fifteen or twenty in number, have a few ganglia developed upon them. They accompany the branches of the renal artery into the kidney; some filaments are distributed to the spermatic plexus and to the ureter, and, on the right side, to the inferior vena cava.

The **spermatic plexus** is derived from the renal plexus, receiving branches from the aortic plexus. It accompanies the testicular artery to the testis. In the female, the **ovarian plexus** arises from the renal plexus, and, accompanying the ovarian artery, is distributed to the ovary, and the fundus of the uterus.

Applied Anatomy.—The intimate connexion which exists between the renal and spermatic plexuses serves to explain the very frequent symptom, in renal calculus, of pain which is referred to the testis.

The **superior mesenteric plexus** is a continuation of the lower part of the cœliac plexus, and receives a branch from the junction of the right vagus nerve with the latter plexus. It surrounds the superior mesenteric artery, accompanies it into the mesentery, and divides into a number of secondary plexuses which are distributed to the parts supplied by the artery, viz. pancreatic branches to the pancreas; jejunal and ileal branches, to the small intestine; ileocolic, right colic, and middle colic branches, which supply the corresponding parts of the great intestine. The nerves composing this plexus are white in colour and firm in texture; in the upper part of the plexus close to the origin of the superior mesenteric artery is the *superior mesenteric ganglion.*

The **abdominal aortic plexus** is formed by branches derived, on either side, from the cœliac plexus and ganglia, and receives filaments from some of the lumbar ganglia. It is situated upon the sides and front of the aorta, between the origins of the superior and inferior mesenteric arteries. From this plexus arise parts of the spermatic, the inferior mesenteric, and the hypogastric plexuses; it also distributes filaments to the inferior vena cava.

The **inferior mesenteric plexus** is derived chiefly from the aortic plexus. It surrounds the inferior mesenteric artery, and just below the origin of this vessel the *inferior mesenteric ganglion* is situated. The plexus divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery; thus the left colic and sigmoid plexuses supply the descending and sigmoid parts of the colon; and the superior hæmorrhoidal plexus supplies the rectum and joins in the pelvis with branches from the pelvic plexuses.

The Hypogastric Plexus (fig. 933)

The **hypogastric plexus** is situated in front of the last lumbar vertebra and the promontory of the sacrum, between the two common iliac arteries. It is formed by the union of numerous filaments, which descend on either side from the aortic plexus, and from the lumbar ganglia. It divides, below, into two lateral portions which are named the *pelvic plexuses.*

The Pelvic Plexuses (fig. 933)

The **pelvic plexuses** supply the viscera of the pelvic cavity, and are situated at the sides of the rectum in the male, and at the sides of the rectum

and vagina in the female. They are formed on either side by a continuation of the hypogastric plexus, by the visceral branches from the second, third, and fourth sacral nerves, and by a few filaments from the first two ganglia of the sacral part of the sympathetic trunk. At the points of junction of these nerves small ganglia are found. From these plexuses numerous branches are distributed to the viscera of the pelvis. They accompany the branches of the hypogastric artery.

The **middle hæmorrhoidal plexus** arises from the upper part of the pelvic plexus; it supplies the rectum, and joins with branches of the superior hæmorrhoidal plexus.

The **vesical plexus** arises from the fore part of the pelvic plexus. The nerves composing it are numerous, and contain a large proportion of spinal nerve-fibres. They accompany the vesical arteries, and are distributed to the sides and fundus of the bladder. Numerous filaments also pass to the vesiculæ seminales and ductus deferentes; those accompanying the ductus deferentes join, on the spermatic cords, with branches from the spermatic plexuses.

The **prostatic plexus** is continued from the lower part of the pelvic plexus. The nerves composing it are of large size. They are distributed to the prostate, vesiculæ seminales, and the corpora cavernosa of the penis and urethra. The nerves supplying the corpora cavernosa consist of two sets, the lesser and greater cavernous nerves, which arise from the fore part of the prostatic plexus, and, after joining with branches from the pudendal nerve, pass forwards beneath the pubic arch.

The *lesser cavernous nerves* perforate the fibrous covering of the penis, near its root, and are distributed to its erectile tissue.

The *greater cavernous nerve* passes forwards along the dorsum of the penis, joins with the dorsal nerve of the penis, and is distributed to the corpora cavernosa.

The **vaginal plexus** arises from the lower part of the pelvic plexus. It is distributed to the walls of the vagina and to the erectile tissue of the vestibule. The nerves composing this plexus contain, like the vesical, a large proportion of spinal nerve-fibres.

The **uterine plexus** accompanies the uterine artery along the side of the uterus, between the layers of the broad ligament, and communicates with the ovarian plexus. Its fibres are chiefly distributed to the neck, and the lower part of the body, of the uterus. At the side of the neck of the uterus is a collection of small ganglia which together form the *uterine cervical ganglion*.

Applied Anatomy.—Little is known as to the connexion between the numerous microscopical alterations (pigmentation, atrophy, hæmorrhage, fibrosis) that have been described in the sympathetic nervous system, and the functional changes that ensue therefrom. Grosser lesions due to stabs, bullet-wounds, or the pressure of new growths, may cause either irritative or paralytic symptoms. In *paralysis* of the cervical sympathetic on one side, the pupil is small and does not dilate when shaded or on the instillation of cocaine, although it contracts still further when brightly illuminated; it also loses the ciliospinal reflex, failing to dilate when the skin of the neck is pinched. The palpebral fissure narrows from paralysis of the involuntary muscle of the eyelid, and the eyeball sinks backwards into the orbit—enophthalmos—either from paralysis of Müller's orbital muscle in the eyelids, which surrounds the eyeball like a conical cuff and tends to produce exophthalmos when it contracts, or from wasting of the intra-orbital fat. The superficial vessels of the face and scalp are at first dilated, but later they contract. Anidrosis, or absence of sweating, is often noted on the affected side. *Irritation* of the cervical sympathetic produces signs mainly the converse of those described above. We have no definite knowledge of the signs and symptoms that follow lesions of the thoracic or abdominal sympathetic systems. It is likely, however, that a number of nervous disorders characterised by persistent vascular disturbances, such as dilatation of the vessels with throbbing, flushing, sweating, and localised œdema, or contraction of the vessels with pallor, chilliness, pain, and malnutrition of the affected parts, are due to implication of the sympathetic nervous system. It is possible, too, that the rare condition of *progressive facial hemiatrophy*, coming on between the ages of ten and twenty, and producing marked unilateral shrinkage of all the tissues on the affected side of the face, is primarily an affection of the sympathetic.

THE ORGANS OF THE SENSES AND THE COMMON INTEGUMENT

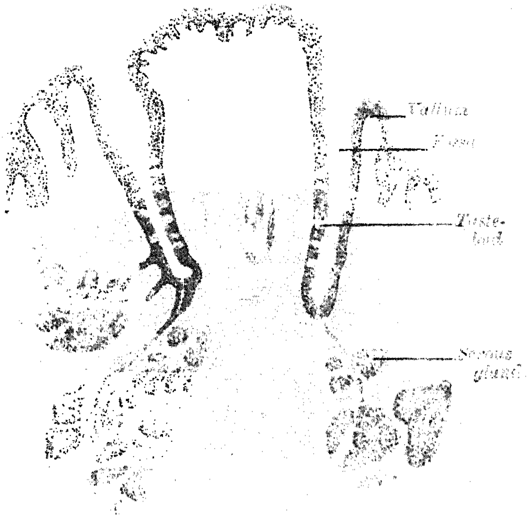
THE **organs of the senses** may be divided into (*a*) those of the special senses of taste, smell, sight, and hearing, and (*b*) those associated with the general sensations of heat, cold, pain, pressure, &c.

THE PERIPHERAL ORGANS OF THE SPECIAL SENSES

The Organ of Taste

The peripheral gustatory organs, or organs of taste, consist of certain modified epithelial cells arranged in flask-shaped groups termed *gustatory calyculi* or *taste-buds*, which are found on the tongue and adjacent parts. They occupy nests in the stratified epithelium (fig. 937), and are very numerous on the sides of the papillæ vallatæ and less so on the walls surrounding the papillæ. They are also found on the fungiform papillæ over the posterior part and sides of the tongue, and in the general epithelial covering of the same areas. They are very plentiful over the folia linguæ, just in front of the lingual attachment of the glossopalatine arch. They are also present on the under surface of the soft palate, and on the posterior surface of the epiglottis.

Fig. 937.—A vertical section through a human papilla vallata. Stained with hæmatoxylin and eosin. × 15.



Structure.—Each taste-bud is flask-shaped (fig. 938), its broad base resting on the corium, and its neck opening by an orifice, the *gustatory pore* between the cells of the epithelium. The bud consists of supporting cells and gustatory cells. The *supporting cells* are mostly arranged like the staves of a cask, and form a complete envelope for the bud. Some, however, are found in the interior of the bud between the gustatory cells. The *gustatory cells* occupy the central portion of the bud; they are spindle-shaped, and each possesses a large spherical nucleus near the middle of the cell. The peripheral process of the cell ends at the gustatory pore in a fine hair-like filament, the *gustatory hair*. The central process passes towards the deep extremity of the bud, and there ends in a single or branched extremity. The nerve-fibres, after losing their medullary sheaths, enter the

gives off a few filaments, which pierce the fascia lata, to supply the skin of the medial side of the thigh, in the neighbourhood of the great saphenous vein; one of these filaments emerges through the fossa ovalis, and a second becomes subcutaneous about the middle of the thigh. The *anterior branch* runs downwards on the Sartorius, perforates the fascia lata at the junction of the middle with the lower one-third of the thigh, and divides into two branches: one supplies the skin as low as the medial side of the knee; the other crosses to the lateral side of the patella, communicating in its course with the infrapatellar branch of the saphenous nerve. The *posterior branch* descends along the posterior border of the Sartorius to the knee, where it pierces the fascia lata, communicates with the saphenous nerve, and gives off several cutaneous branches. It then passes down to supply the skin of the medial side of the leg. Beneath the fascia lata, at the lower border of the Adductor longus, it joins to form a plexiform network (*subsartorial plexus*) with branches of the saphenous and obturator nerves. When the communicating branch from the obturator nerve is large and continued to the skin of the leg, the posterior branch of the medial cutaneous is small, and terminates in the plexus, occasionally giving off a few cutaneous filaments. The *nerve to the Pectineus* arises just below the inguinal ligament, passes behind the femoral sheath and enters the anterior surface of the muscle; it is often duplicated. The *nerve to the Sartorius* arises in common with the intermediate cutaneous nerve.

The posterior division of the femoral nerve gives off the saphenous nerve, and supplies muscular branches to the Quadriceps femoris, and articular branches to the knee-joint.

The **saphenous nerve** (long or internal saphenous nerve) (fig. 922) is the largest cutaneous branch of the femoral nerve. It descends on the lateral side of the femoral artery and enters the adductor canal (p. 690) where it crosses the artery obliquely from its lateral to its medial side. At the lower end of the canal it quits the artery, and emerges through the aponeurotic covering of the canal, accompanied by the saphenous branch of the highest genicular artery. It descends vertically along the medial side of the knee behind the Sartorius, pierces the fascia lata, between the tendons of the Sartorius and Gracilis, and becomes subcutaneous. It then passes along the tibial side of the leg, accompanied by the great saphenous vein, descends behind the medial border of the tibia, and, at the lower third of the leg, divides into two branches: one continues its course along the margin of the tibia, and ends at the ankle; the other passes in front of the ankle, and is distributed to the skin on the medial side of the foot, as far as the ball of the great toe, communicating with the medial branch of the superficial peronæal nerve.

About the middle of the thigh, the saphenous nerve gives a branch to join the subsartorial plexus.

At the medial side of the knee it gives off a large *infrapatellar branch* (fig. 920) which pierces the Sartorius and fascia lata, and is distributed to the skin in front of the patella. Above the knee this nerve unites with the medial and intermediate branches of the femoral nerve; below the knee, with other branches of the saphenous nerve; and, on the lateral side of the joint, with branches of the lateral femoral cutaneous nerve, forming a plexiform network, the *plexus patellæ.* The infrapatellar branch is occasionally small.

The *muscular branches* of the posterior division of the femoral nerve supply the Quadriceps femoris. The branch to the Rectus femoris enters the upper part of the deep surface of the muscle, and supplies a filament to the hip-joint. The branch to the Vastus lateralis, of large size, accompanies the descending branch of the lateral femoral circumflex artery to the lower part of the muscle and sends an articular filament to the knee-joint. The branch to the Vastus medialis descends through the upper part of the adductor canal, on the lateral side of the saphenous nerve and the femoral vessels. It enters the muscle about its middle, and gives off a filament, which can usually be traced downwards on the surface of the muscle, to the knee-joint. The branches to the Vastus intermedius, two or three in number, enter the anterior surface of the muscle about the middle of the thigh; a filament from one of these descends through the muscle to the Articularis genus and the knee-joint.

of the septum, but its lower part is separated from this cartilage by a narrow fissure; its superior margin is attached to the nasal bone and the frontal process of the maxilla; its inferior margin is connected by fibrous tissue with the crus laterale of the greater alar cartilage.

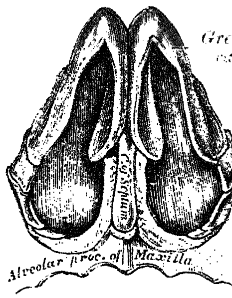
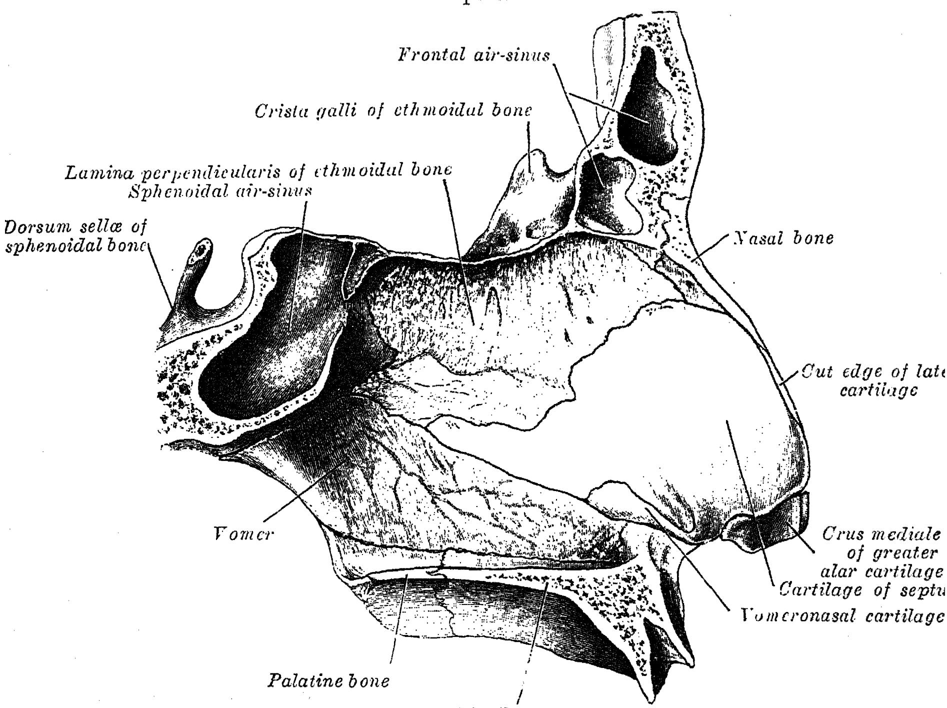


FIG. 940.—The cartilages of the nose. Inferior aspect.

The *greater alar cartilage* (figs. 939, 940) is a thin, flexible plate, situated immediately below the lateral cartilage, and bent upon itself anteriorly in such a manner as to form the medial, anterior, and lateral walls of the naris. The portion which forms the medial wall (*crus mediale*) is narrow, and is loosely connected with the crus mediale of the opposite cartilage and with the antero-inferior border of the cartilage of the septum; the medial crura of the greater alar cartilages constitute, together with the thickened skin and subjacent tissue, the septum mobile nasi. The part which forms the lateral wall (*crus laterale*) is curved to correspond with the ala of the nose; its posterior end is narrow, and is connected with the frontal process of the maxilla by a tough fibrous membrane, in which are found three or four small cartilaginous plates, the *lesser alar cartilages*. Its upper

FIG. 941.—The bones and cartilages of the septum of the nose. Right lateral aspect.



edge is connected by fibrous tissue to the lateral cartilage, its lower edge falls short of the lateral margin of the naris, the lower part of ala nasi being formed by fatty and fibrous tissue covered with skin. In front, the greater alar cartilages are separated by a notch which corresponds with the apex of the nose.

The *muscles* acting on the external nose have been described on p. 440.

The *skin* of the dorsum and sides of the nose is thin, and loosely connected with the subjacent parts; but over the tip and alæ it is thicker and more firmly adherent, and is

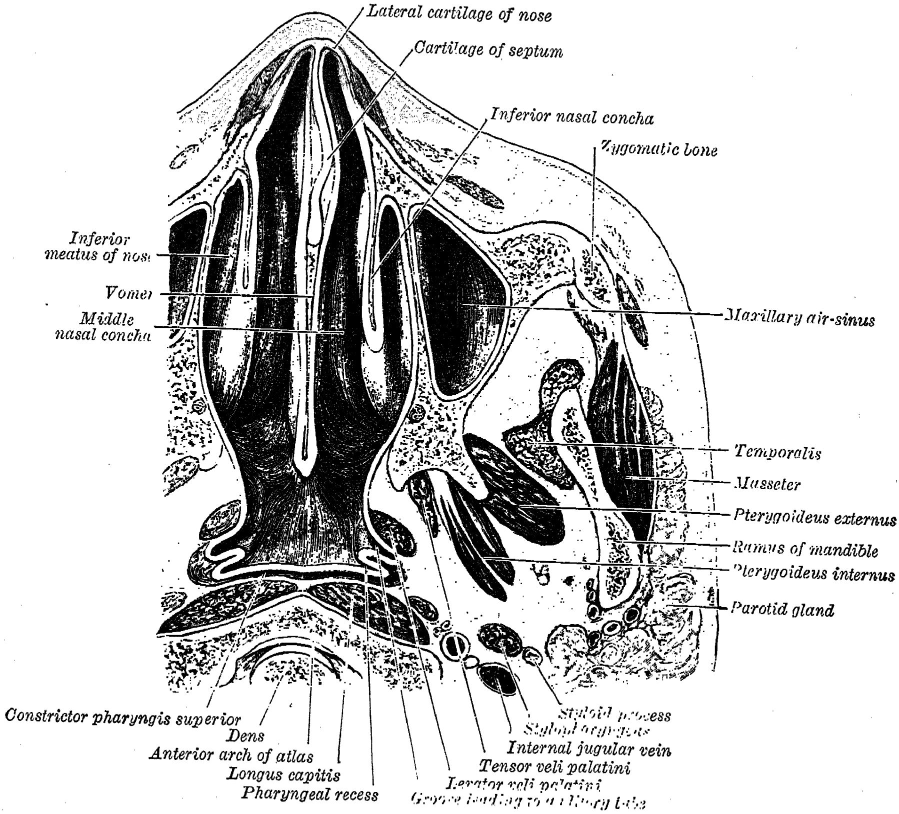
furnished with a large number of sebaceous follicles, the orifices of which are usually very distinct.

The *arteries* of the external nose are the alar and septal branches of the external maxillary artery, which supply the alæ and lower part of the septum; the dorsum and sides being supplied from the dorsal nasal branch of the ophthalmic artery and the infra-orbital branch of the internal maxillary artery. The *veins* end in the anterior facial and ophthalmic veins.

The *nerves* for the muscles of the nose are derived from the facial nerve, while the skin receives branches from the infratrochlear and anterior ethmoidal branches of the ophthalmic nerve, and from the infra-orbital branch of the maxillary nerve.

Nasal cavities.—The nasal cavities or chambers are situated one on either side of the median plane (fig. 942). They open in front through the nares, and communicate behind with the nasal part of the pharynx through the

Fig. 942.—A transverse section through the anterior part of the head at a level just below the apex of the dens (odontoid process). Viewed from below.



choanæ. The *nares* are somewhat pear-shaped apertures, each measuring from 1·5 cm. to 2 cm. anteroposteriorly, and from 0·5 cm. to 1 cm. transversely at its widest part. The *choanæ* are two oval openings each measuring about 2·5 cm. in the vertical, and 1·25 cm. in the transverse direction.

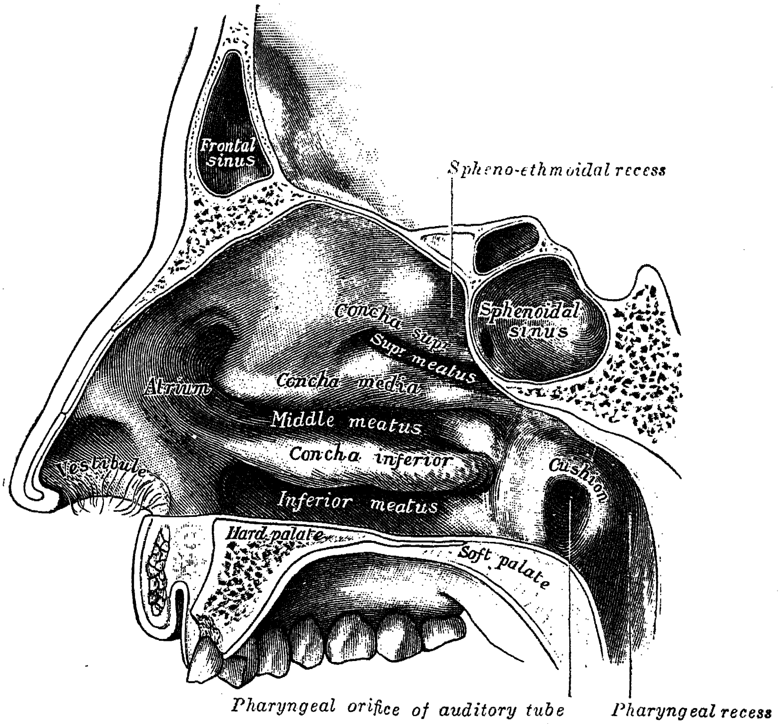
For the description of the bony boundaries of the nasal cavities, see p. 264.

Inside the aperture of the nostril is a slight dilatation, the *vestibule* (fig. 943), bounded laterally by the ala and the lateral crus of the greater alar cartilage, and medially by the medial crus of the same cartilage; it extends as a small recess towards the apex of the nose. The vestibule is lined by skin, and in its lower part are coarse hairs and sebaceous glands; the hairs (vibrissæ) curve downwards and forwards and tend to arrest the passage of foreign substances carried with the current of inspired air. The vestibule is limited above and behind by a curved elevation, the *limen nasi*, along which the cutaneous lining of the vestibule is continuous with the mucous membrane of the nasal cavity.

Each nasal cavity, above and behind the vestibule, is divided into two parts: an *olfactory* region, limited to the superior nasal concha and the opposed part of the septum, and a *respiratory* region, which comprises the rest of the cavity.

Lateral wall (figs. 943, 944).—On the lateral wall are the superior, middle, and inferior nasal conchæ, and below and lateral to each concha is the corresponding nasal passage or meatus. Above the superior concha is a triangular fossa, the *spheno-ethmoidal recess*, into which the sphenoidal air-sinus opens. The *superior meatus* is a short oblique passage extending about half-way along the upper border of the middle concha; the posterior ethmoidal air-sinuses open, usually by two apertures, into the front part of this meatus.

FIG. 943.—The lateral wall of the right nasal cavity. Medial aspect.

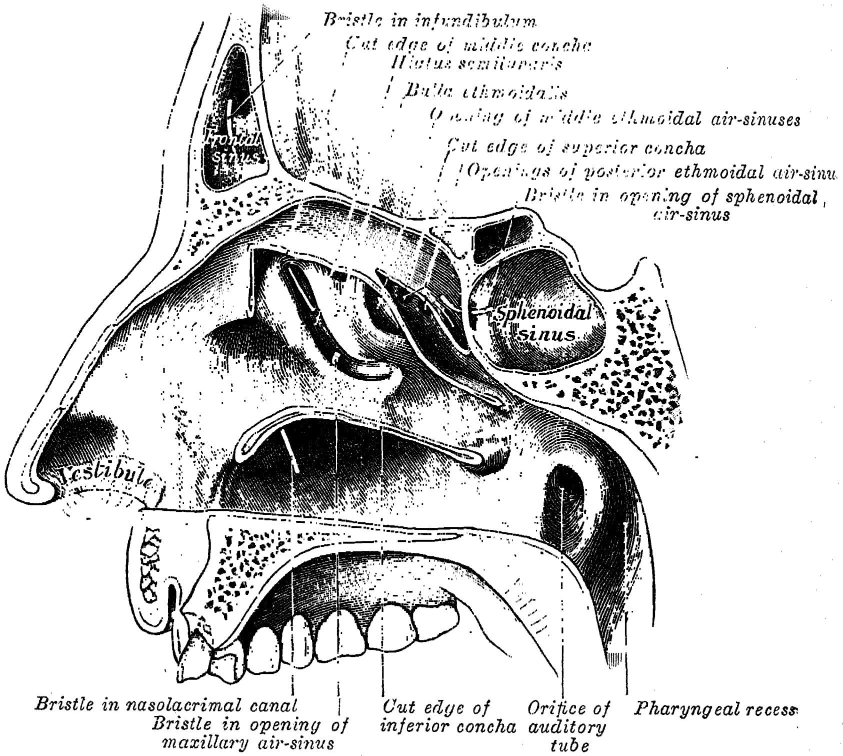


The *middle meatus*, deeper in front than behind, is below and lateral to the middle concha, and is continued anteriorly into a shallow depression, situated above the vestibule and named the *atrium* of the middle meatus. Above the atrium a flattened ridge, the *agger nasi*, runs forwards and downwards; it is better developed in the new-born child than in the adult; the furrow above it is named the *sulcus olfactorius*. On raising or removing the middle concha the lateral wall of this meatus is fully displayed. On it is a round elevation, the bulla ethmoidalis, and below and in front of this is a curved cleft, the hiatus semilunaris. The *bulla ethmoidalis* is caused by the bulging of the middle ethmoidal air-sinuses which open on or immediately above it, and the size of the bulla varies with that of its contained sinuses. The *hiatus semilunaris* is bounded inferiorly by the sharp concave margin of the uncinate process of the ethmoidal bone, and leads into a curved channel, the *infundibulum*, bounded above by the bulla ethmoidalis and below by the lateral surface of the uncinate process of the ethmoidal bone. The anterior ethmoidal air-sinuses open into the front part of the infundibulum; the latter in rather more than 50 per cent. of subjects is continuous with the frontonasal duct or passage leading from the frontal air-sinus; but in those cases where the anterior end of the uncinate process fuses with the front part of the bulla, this continuity is

interrupted and the frontonasal duct then opens directly into the anterior end of the middle meatus. Below the bulla ethmoidalis, and partly hidden by the inferior end of the uncinate process, is the *ostium maxillare*, or opening from the maxillary air-sinus; in a frontal section of the nose this opening is seen to be placed near the roof of the sinus. An accessory opening from the maxillary air-sinus is frequently present below and behind the infundibulum. The *inferior meatus* is below and lateral to the inferior nasal concha; the nasolacrimal duct opens into this meatus under cover of the anterior part of the inferior concha.

Medial wall (fig. 941).—The medial wall or septum is frequently more or less deflected from the median plane, thus lessening the size of one nasal cavity

FIG. 944.—The lateral wall of the right nasal cavity; the three nasal conchæ have been removed.



and increasing that of the other; ridges or spurs of bone sometimes project into one or other cavity from the septum. Immediately over the incisive canal at the lower edge of the cartilage of the septum a depression, the *nasopalatine recess*, is sometimes seen; it points downwards and forwards, and occupies the position of a canal which connected the nasal with the buccal cavity in early fœtal life. In the septum close to this recess a minute orifice may be discerned; it leads backwards into a blind pouch, the rudimentary *vomeronasal organ of Jacobson*, which is supported by a strip of cartilage, the *vomeronasal cartilage*. This organ is well developed in many of the lower animals, where it apparently plays a part in the sense of smell, since it is supplied by twigs of the olfactory nerve and is lined by epithelium similar to that in the olfactory region of the nose.

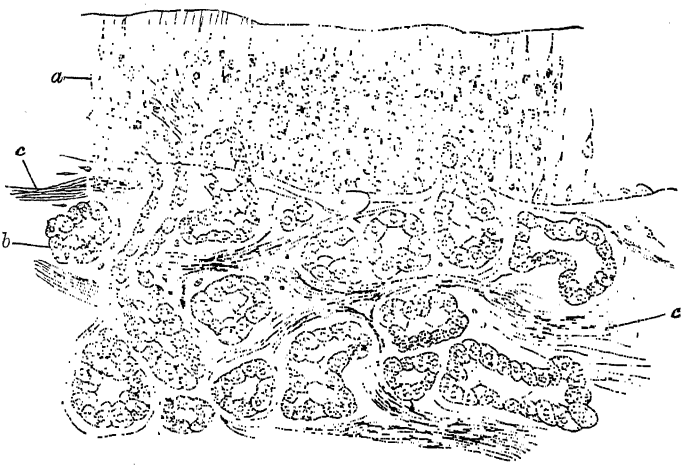
The *roof* of the nasal cavity is narrow from side to side, except at its posterior part, and may be divided, from behind forwards, into sphenoidal, ethmoidal, and frontonasal parts, corresponding to the bones which enter into its formation.

The *floor* is concave from side to side, flat and almost horizontal antero-posteriorly; its anterior three-fourths are formed by the palatine process of the maxilla, its posterior one-fourth by the horizontal part of the palatine bone.

The **nasal mucous membrane** lines the nasal cavities with the exception of the vestibules, and is intimately adherent to the periosteum or perichondrium. It is continuous with the mucous membrane of the nasal part of the pharynx, through the choanæ; with the conjunctiva, through the nasolacrimal and lacrimal ducts; and with the mucous membranes of the sphenoidal, ethmoidal, frontal, and maxillary air-sinuses, through the openings of these sinuses.

The mucous membrane is thickest and most vascular over the nasal conchæ, especially at their extremities. It is also thick over the septum nasi, but very thin in the meatuses, on the floor of the nasal cavities, and in the various air-sinuses. Owing to the thickness of the membrane, the nasal cavities are much narrower, and the middle and inferior nasal conchæ larger and more prominent than they appear in the skeleton; for the same reason the various apertures communicating with the meatuses are also considerably narrowed.

FIG. 945.—A section through the olfactory mucous membranes. (Cadiat.)



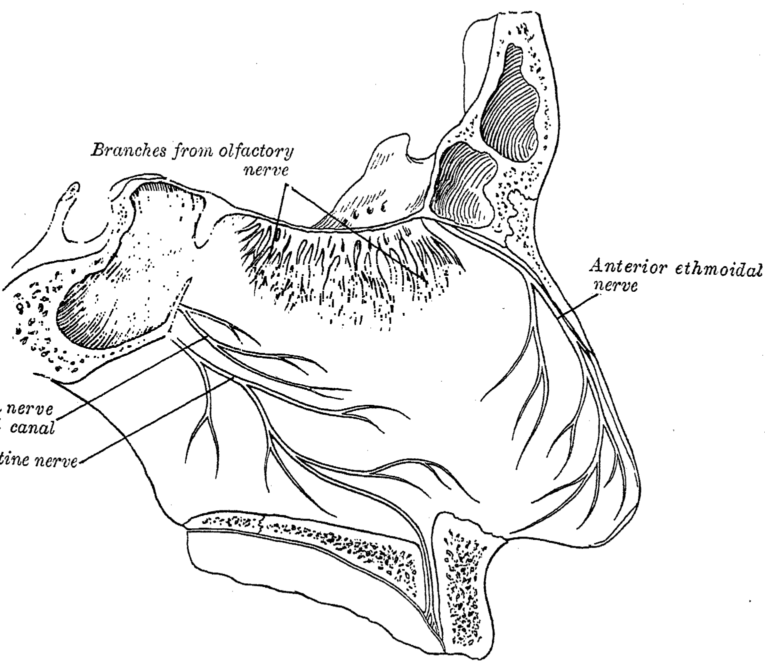
a. Epithelium. *b.* Glands of Bowman. *c.* Nerve-bundles.

Structure of the mucous membrane (fig. 945).—The epithelium of the mucous membrane differs in its characteristics according to the functions of the part of the nose in which it is found. In the *respiratory region* it is columnar and ciliated. Interspersed among the columnar cells are goblet or mucous cells, while between their bases are found smaller pyramidal cells. Beneath the epithelium and its basement-membrane is a fibrous layer infiltrated with lymph-corpuscles, forming in many parts a diffuse adenoid tissue, and under this a nearly continuous layer of mucous and serous glands, the ducts of which open upon the surface. In the *olfactory region* the mucous membrane is yellowish in colour and the epithelial cells are of two kinds, supporting cells and olfactory cells. The *supporting cells* contain oval nuclei, which are situated in the deeper parts of the cells and constitute the zone of oval nuclei; the superficial part of each cell is columnar, and contains granules of yellow pigment, while its deep part is prolonged as a delicate process which ramifies, and communicates with similar processes from neighbouring cells so as to form a network in the mucous membrane. Lying between the deep processes of the supporting cells are a number of bipolar nerve-cells, the *olfactory cells*, each consisting of a small amount of granular protoplasm with a large spherical nucleus, and possessing two processes—a superficial process which runs between the columnar epithelial cells, and ends at the surface of the mucous membrane in one or more fine, hair-like processes, the *olfactory hairs*; the deep process runs inwards, is frequently beaded, and is continued as an olfactory nerve-fibre (p. 885). Beneath

the epithelium, and extending through the thickness of the mucous membrane, is a layer of tubular, often branched, glands, the *glands of Bowman*, similar in structure to serous glands.

Vessels and Nerves.—The *arteries* of the nasal cavities are the anterior and posterior ethmoidal branches of the ophthalmic artery, which supply the ethmoidal and frontal air-sinuses, and the roof of the nose; the sphenopalatine branch of the internal maxillary artery, which supplies the mucous membrane covering the conchæ, the meatuses, and septum; the septal ramus of the superior labial branch of the external maxillary artery; the infra-orbital and alveolar branches of the internal maxillary artery, which supply the lining membrane of the maxillary air-sinus; and the pharyngeal branch of the same artery, distributed to the sphenoidal air-sinus. The ramifications of these vessels form a close plexiform network, beneath and in the substance of the mucous membrane.

FIG. 946.—The nerves of the right side of the septum of the nose.



The *veins* form a close cavernous plexus beneath the mucous membrane. This plexus is especially marked over the lower part of the septum and over the middle and inferior conchæ. Some of the veins open into the sphenopalatine vein; others join the anterior facial vein; some accompany the ethmoidal arteries, and end in the ophthalmic veins; a few communicate with the veins on the orbital surface of the frontal lobe of the brain, through the foramina in the lamina cribrosa of the ethmoidal bone. When the foramen cæcum is patent it transmits a vein from the nasal cavity to the superior sagittal sinus.

The *lymphatics* are described on p. 755.

The *nerves* of ordinary sensation (figs. 885, 946) are: the anterior ethmoidal branch of the nasociliary nerve, filaments from the anterior alveolar branch of the maxillary nerve, the nerve of the pterygoid canal, the nasopalatine nerve, the anterior palatine and nasal branches of the sphenopalatine ganglion.

The anterior ethmoidal branch of the nasociliary nerve distributes filaments to the anterior parts of the septum and lateral wall. Filaments from the anterior alveolar nerve supply the inferior meatus and inferior concha. The nerve of the pterygoid canal supplies the upper and posterior parts of the septum, and superior concha; and the upper nasal branches from the sphenopalatine ganglion have a similar distribution. The nasopalatine nerve supplies the middle of the septum. The anterior palatine nerve supplies the lower nasal branches to the middle and inferior conchæ.

The *olfactory nerves* are distributed to the olfactory region. Their fibres arise from the bipolar olfactory cells and are destitute of medullary sheaths. They unite in fasciculi which cross one another in various directions, and thus give rise to the appearance of a plexus in the mucous membrane (fig. 946) and then ascend in grooves or canals in the ethmoidal bone; they pass into the skull through the foramina in the lamina cribrosa of

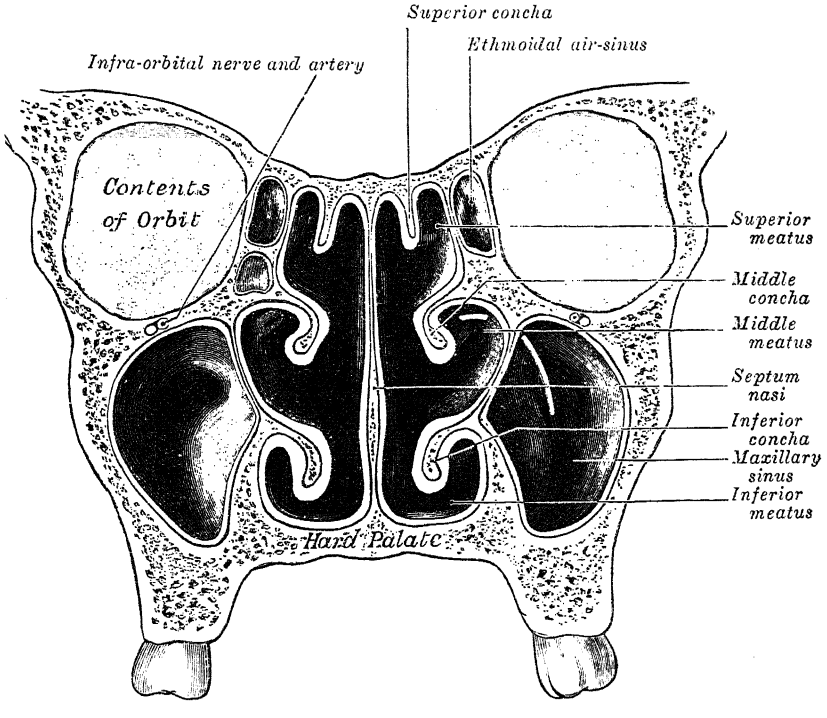
the ethmoidal bone and enter the under surface of the olfactory bulbs, in which they ramify and form synapses with the dendrites of the mitral cells (fig. 876). Closely associated with the olfactory nerves are the *nervi terminales* (p. 885*).

The Accessory Air-sinuses of the Nose (figs. 942, 943, 944, 947)

The **accessory air-sinuses of the nose** are the frontal, ethmoidal, sphenoidal, and maxillary; they vary in size and form in different individuals, and are lined by mucous membrane continuous with that of the nasal cavities.

The **frontal air-sinuses,** two in number, are situated behind the superciliary arches; they are rarely symmetrical, and the septum between them frequently deviates to one or other side of the middle line. Their average measurements are as follows: height, 3·16 cm.; breadth, 2·58 cm.; depth from before backwards,

Fig. 947.—A coronal section through the nasal cavities.



1·8 cm. Each opens into the anterior part of the corresponding middle meatus of the nose through the frontonasal duct, which traverses the anterior part of the labyrinth of the ethmoid. Small at birth, they are generally fairly well developed between the seventh and eighth years, but only reach their full size after puberty.

The **ethmoidal air-sinuses** consist of numerous thin-walled cavities situated in the ethmoidal labyrinth, and completed by the frontal, maxillary, lacrimal, sphenoidal and palatine bones. They lie between the upper parts of the nasal cavities and the orbits, and are separated from the latter by the laminæ papyraceæ. On either side they are arranged in three groups, anterior, middle, and posterior. The anterior and middle groups open into the middle meatus of the nose, the former by way of the infundibulum, the latter on or above the bulla ethmoidalis. The posterior air-sinuses open into the superior meatus under cover of the superior nasal concha; sometimes one or more opens into the sphenoidal air-sinus. The ethmoidal air-sinuses begin to develop during fœtal life.

The **sphenoidal air-sinuses,** two in number, are placed behind the upper parts of the nasal cavities, and are contained within the body of the sphenoidal bone. Above them are the optic chiasma and the hypophysis cerebri (pituitary body);

lateral to them are the internal carotid arteries and the cavernous sinuses. They vary in size and shape, and, owing to the lateral displacement of the intervening septum, are rarely symmetrical. The following are their average measurements: vertical height, 2 cm.; transverse breadth, 1·8 cm.; antero-posterior depth, 2·1 cm. When exceptionally large they may extend into the roots of the pterygoid processes or great wings, and may invade the basilar part of the occipital bone. Each air-sinus communicates with the spheno-ethmoidal recess by an aperture in the upper part of its anterior wall. They are present as minute cavities at birth, but their main development takes place after puberty.

The **maxillary air-sinuses** or **antra of Highmore,** the largest accessory air-sinuses of the nose, are pyramidal cavities in the bodies of the maxillæ. The base of each is formed by the lateral wall of the nasal cavity; the apex extends into the zygomatic process. The roof or orbital wall is frequently ridged by the infra-orbital canal, while the floor is formed by the alveolar process and is usually about 1·25 cm. below the level of the floor of the nose; projecting into the floor are several conical elevations corresponding with the roots of the first and second molar teeth, and in some cases the floor is perforated by one or more of these roots. The size of the maxillary air-sinus varies in different skulls, and even on the two sides of the same skull; when large, its apex may invade the zygomatic bone. The following measurements are those of an average-sized air-sinus: vertical height opposite the first molar tooth, 3·5 cm.; transverse breadth, 2·5 cm.; anteroposterior depth, 3·2 cm. In the anterosuperior part of its base is an opening through which it communicates with the lower part of the hiatus semilunaris; a second orifice is frequently seen in, or immediately behind, the hiatus. The maxillary air-sinus appears as a shallow groove on the medial surface of the bone about the fourth month of fœtal life, but does not reach its full size until after the second dentition.*

Applied Anatomy.—Instances of congenital deformity of the nose are occasionally met with, such as complete absence of the external nose, an aperture only being present, or perfect development on one side, and suppression or malformation on the other. Deformities which have been acquired are much more common, such as flattening of the nose, the result of syphilitic necrosis; or imperfect development of the nasal bones in cases of congenital syphilis; or a lateral deviation of the nose after fracture.

The septum of the nose may be displaced or may deviate from the middle line as a result of an injury or of some congenital defect. Sometimes the deviation may be so great that the septum may come into contact with the lateral wall of the nasal cavity, producing complete unilateral obstruction. The septum is covered by a mucous membrane intimately connected with the periosteum; in cases of deflection of the septum, *submucous resection* is frequently necessary, the septal cartilage and the vomer being shelled out from the mucoperiosteum clothing them. Perforation of the septum is not uncommon, and most often results from syphilitic ulceration.

Enlargement of the mucous membrane covering the inferior or middle nasal conchæ is a very frequent accompaniment of chronic nasal catarrh. In old-standing cases the bones themselves may become enlarged, constituting the 'hypertrophied turbinals' which so often cause nasal obstruction. In the case of the inferior concha either the anterior or posterior end is usually more especially affected, giving rise to a reddened mass of tissue often confused with a nasal polypus; the appearances, however, are totally different, as the true nasal polypi appear as glistening greyish-white bodies between the conchæ.

Nasal polypi are of frequent occurrence; in the common gelatinous form they spring from the lateral wall of the nasal cavity and project down between the conchæ, giving rise to obstructed nasal respiration. They are always accompanied by purulent discharge, and are due in all instances to small areas of carious bone in the region of the *bulla ethmoidalis*, or about the ethmoidal or sphenoidal air-sinuses. In bad cases a free curetting of the ethmoidal air-sinuses may be called for after removal of the middle concha. Fibrous polypi are also more rarely met with, and these are of the nature of new growths; they most frequently spring from the base of the skull behind the choanæ and form pedunculated tumours occupying the nasopharynx. Malignant polypi also occur, most commonly originating in the maxillary air-sinus and projecting through its medial wall into the nasal cavity; for such cases removal of the maxilla offers the only hope of cure.

Suppuration in the accessory air-sinuses of the nose is of frequent occurrence, and in connexion with this the situations at which the various sinuses normally communicate with the nasal cavities, are important: thus one finds they fall into two main groups: (1) anterior, opening into the middle meatus, and draining the maxillary, the frontal, and the anterior ethmoidal air-sinuses; and (2) posterior, opening into the superior meatus and spheno-ethmoidal recess, and draining the posterior ethmoidal and sphenoidal

* The measurements of the accessory air-sinuses of the nose supplied in the text are those given by A. Logan Turner, *Accessory Sinuses of the Nose*, 1901.

air-sinuses. Suppuration in the anterior group is the more common, and the pus can be seen running down over the anterior end of the inferior concha, whereas in the case of the posterior group, the pus does not come forwards, but runs back into the nasopharynx over the posterior end of the middle concha. Again, it is of importance to notice that the middle meatus is of such a form that pus running down from the frontal air-sinus is directed by the groove beneath the bulla ethmoidalis into the ostium of the maxillary air-sinus, so that the latter sinus may, in some cases, act as a secondary reservoir for pus discharged from the frontal air-sinus. All the accessory air-sinuses can be and are infected from the nasal cavity, but it should be noted that in the case of the maxillary air-sinus, the infection is frequently conveyed in another way, and that is from the teeth. This air-sinus is the one most frequently the seat of chronic suppuration and it often requires drainage; this can be carried out by drilling a hole through the alveolus after removal of a tooth, preferably the first molar, or by gouging away the anterior surface of the maxilla, after having reflected the gum, or by removing bone from the lateral wall of the inferior meatus of the nose. Simple drainage, however, is not usually sufficient, and more extensive operations have often to be performed. Distension of the walls of the maxillary air-sinus occurs as the result of new growth or cyst formation within its cavity. Thus the facial surface may be prominently bulged outwards, upward extension may displace the eyeball, or the nasal cavity on that side may be occluded, giving rise to unilateral obstruction. In some cases the disease will perforate the palatine process of the maxilla and a soft spot will be found under the mucoperiosteum. If the disease be malignant in nature, nothing short of excision of the maxilla is of any avail (p. 273).

The Organ of Sight

The bulb of the eye (eyeball), or organ of sight, is contained in the cavity of the orbit, where it is protected from injury, and can be moved by the ocular muscles. Associated with it are certain accessory structures, viz. the muscles, fasciæ, eyebrows, eyelids, conjunctiva, and lacrimal apparatus.

The **bulb of the eye** is embedded in the fat of the orbit, but is separated from the fat by a thin membranous sac, the *fascia bulbi* (p. 1013). It is composed of segments of two hollow spheres of different sizes. The anterior segment is one of a small sphere; it is transparent, and its arc forms about one-sixth of the circumference of the bulb. It is more prominent than the posterior segment, which is one of a larger sphere, and is opaque, and forms about five-sixths of the bulb. The term *anterior pole* is applied to the central point of the anterior curvature of the bulb, and that of *posterior pole* to the central point of its posterior curvature; a line joining the two poles forms the *optic axis*. The axes of the two bulbs are nearly parallel, and therefore do not correspond with the axes of the orbits, which are directed forwards and lateralwards. The optic nerves follow the direction of the axes of the orbits, and are therefore not parallel; each enters its eyeball 3 mm. to the nasal side of the posterior pole. The vertical diameter (23·5 mm.) of the bulb is rather less than the transverse and anteroposterior diameters (24 mm.); the anteroposterior diameter at birth is about 17·5 mm. and at puberty from 20 to 21 mm. In the female all three diameters are rather less than in the male.

The bulb of the eye is composed of three tunics, enclosing three refracting media.

The Tunics of the Eye (fig. 948)

From without inwards the three tunics are: (1) the fibrous tunic, consisting of the *sclera* behind and the *cornea* in front; (2) the vascular, pigmented tunic, comprising, from behind forwards, the *chorioid*, *ciliary body*, and *iris*; and (3) the nervous tunic, the *retina*.

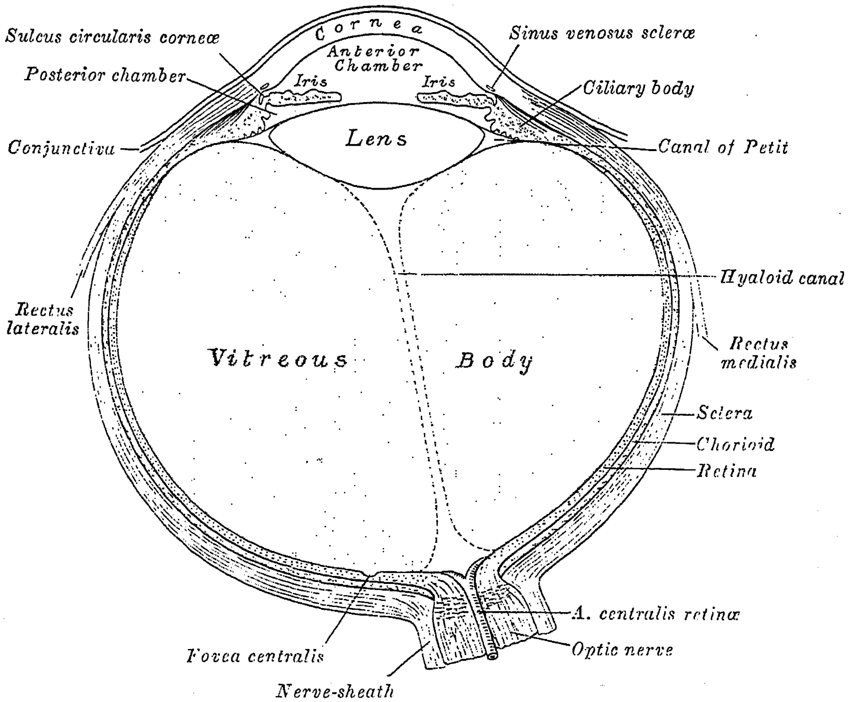
I. The Fibrous Tunic

The fibrous tunic of the bulb of the eye (fig. 948) consists of an opaque, posterior part, the sclera, and a transparent anterior part, the cornea.

The **sclera**, so named from its density and hardness, is a firm unyielding membrane, serving to maintain the form of the bulb. It is thickest (about 1 mm.) behind, near the entrance of the optic nerve, and thinnest (0·4 mm.) at

a distance of about 6 mm. behind the sclerocorneal junction. Its *external surface* is white, and is in contact with the inner surface of the fascia bulbi (p. 1013); it is smooth, except where the Recti and Obliqui muscles are inserted into it; its anterior part is covered by the conjunctival membrane. Its *inner surface* is brown and is marked by grooves, in which the ciliary nerves and vessels are lodged; it is separated from the outer surface of the chorioid by an extensive *perichorioidal lymph-space*, which is traversed by an exceedingly fine cellular tissue, the *lamina suprachorioidea*. Behind, it is pierced by the optic nerve, and is continuous through the fibrous sheath of this nerve with the dura mater. Where the optic nerve pierces the sclera the latter presents the appearance of a cribriform plate, the *lamina cribrosa scleræ*; the minute orifices in this lamina serve for the transmission of the nerve-bundles, and the fibrous septa between the orifices are continuous with the supporting tissue of the nerve.

FIG. 948.—A horizontal section through the bulb of the eye.



One opening, larger than the rest, and occupying the centre of the lamina, transmits the central artery and vein of the retina. Around the lamina cribrosa scleræ are numerous small apertures for the transmission of the ciliary vessels and nerves, and about midway between these and the sclerocorneal junction are four or five large apertures for the transmission of veins (*venæ vorticosæ*). In front, the sclera is directly continuous with the cornea, the line of union being termed the *sclerocorneal junction*. In the substance of the sclera close to this junction is a circular canal, the *sinus venosus scleræ* (canal of Schlemm). In a meridional section through the sclerocorneal junction, this sinus presents the appearance of a cleft, the outer wall of which consists of the firm tissue of the sclera, while its inner wall is formed by a triangular mass of trabecular tissue (fig. 949); the apex of the mass is directed forwards and is continuous with the posterior elastic lamina of the cornea. The sinus is lined by endothelium, and communicates internally with the anterior chamber of the eye, and externally with the anterior ciliary veins.

Structure.—The sclera is formed of white fibrous tissue intermixed with fine elastic fibres; flattened connective tissue corpuscles, some of which are pigmented, are contained in cell-spaces between the fibres. The fibres are aggregated into

bundles, which are arranged chiefly in a longitudinal direction. Its *vessels* are not numerous; its capillaries are small, and unite at long and wide intervals. Its *nerves* are derived from the ciliary nerves, but their exact mode of ending is not known.

The **cornea** is the anterior projecting transparent part of the external tunic; it is almost circular in outline, occasionally a little broader in the transverse than in the vertical direction. It is convex anteriorly, and projects like a dome in front of the sclera. Its degree of curvature varies in different individuals, and in the same individual at different periods of life, being more pronounced in youth than in advanced life. The cornea is

Fig. 949.—A general view of the iridial angle. Enlarged. (After Thomson.)

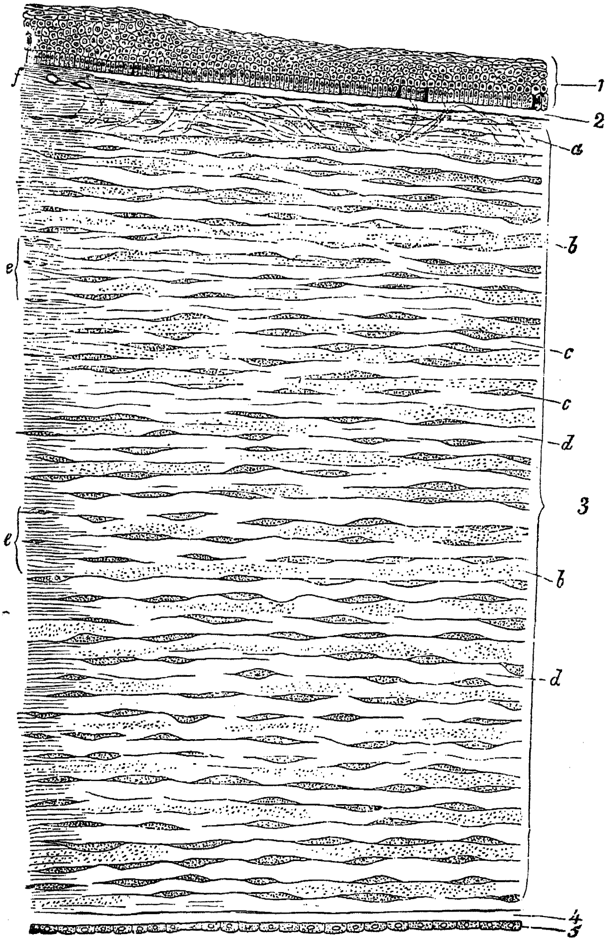
dense and of uniform thickness throughout; its posterior surface is perfectly circular in outline, and exceeds the anterior surface slightly in diameter. Immediately in front of the sclerocorneal junction the cornea bulges inwards as a thickened rim, and behind this rim there is a distinct furrow between the attachment of the iris and the sclerocorneal junction. This furrow has been named by Arthur Thomson * the *sulcus circularis corneæ*; it is bounded externally by the trabecular tissue already described as forming the inner wall of the sinus venosus scleræ. Between this tissue and the anterior surface of the attached margin of the iris is an angular recess, named the *iridial angle* or *filtration angle* of the eye (fig. 949). Immediately outside the filtration angle is a projecting rim of scleral tissue which appears in a meridional section as a small triangular area, termed the *scleral spur*. Its base is continuous with the inner surface of the sclera immediately to the outer side of the filtration angle and its apex is directed forwards and inwards. The bundles of trabecular tissue just referred to are attached to the anterior sloping margin

* *Atlas of the Eye*, Clarendon Press, Oxford, 1912.

of this spur; the meridional fibres of the Ciliaris muscle arise from its posterior margin.

Structure (fig. 950).—The cornea consists from before backwards of four layers, viz.: (1) the corneal epithelium, continuous with that of the conjunctiva; (2) the substantia propria; (3) the posterior elastic lamina; and (4) the endothelium of the anterior chamber.

FIG. 950.—A vertical section through the human cornea near its margin. Magnified. (Waldeyer.)



1. Epithelium. 2. Anterior elastic lamina. 3. Substantia propria. 4. Posterior elastic lamina. 5. Endothelium of the anterior chamber. *a.* Oblique fibres in the anterior layer of the substantia propria. *b.* Lamellæ the fibres of which are cut across, producing a dotted appearance. *c.* Corneal corpuscles appearing fusiform in section. *d.* Lamellæ the fibres of which are cut longitudinally. *e.* Transition to the sclera, with more distinct fibrillation, and surmounted by a thicker epithelium. *f.* Small blood-vessels cut across near the margin of the cornea.

The *corneal epithelium* covers the front of the cornea and consists of several layers of cells. The cells of the deepest layer are columnar; then follow two or three layers of polyhedral cells, the majority of which are prickle-cells similar to those found in the stratum mucosum of the cuticle (p. 1053). Lastly, there are three or four layers of squamous cells, with flattened nuclei.

The *substantia propria* is fibrous, tough, unyielding, and perfectly transparent. It is composed of about sixty flattened, superimposed lamellæ. These lamellæ are made up of bundles of modified connective tissue, the fibres of which are continuous with those of the sclera. The fibres of each lamina are for the most part parallel with one another, but at right angles to those of adjacent lamellæ. Fibres, however, frequently pass from one lamella to the next.

Between the lamellæ is a small amount of ground-substance, in which are spaces, the *corneal spaces*. These are stellate in shape and communicate with one another by numerous offsets. Each contains a cell, the *corneal corpuscle*, resembling in form the space in which it is lodged, but not entirely filling it.

The layer immediately beneath the corneal epithelium presents certain characteristics which have led some anatomists to regard it as a distinct membrane, and it has been named the *anterior elastic lamina*. It consists of extremely closely interwoven fibrils, similar to those found in the substantia propria, but contains no corneal corpuscles.

The *posterior elastic lamina* covers the posterior surface of the substantia propria, and is a thin elastic, transparent homogeneous membrane, which is not rendered opaque, by water, alcohol, or acids. When stripped from the substantia propria it curls up, and rolls upon itself, with the attached surface innermost.

At the margin of the cornea the posterior elastic lamina breaks up into fibres which form the trabecular tissue on the inner wall of the sinus venosus scleræ

(p. 994); the spaces between the trabeculæ are termed the *spaces of the angle of the iris* (spaces of Fontana); they communicate with the sinus venosus scleræ and with the anterior chamber at the filtration angle. Some of the fibres of this trabecular tissue are continued into the substance of the iris, forming the *pectinate ligament of the iris*; others are connected with the fore part of the sclera and chorioid.

The *endothelium of the anterior chamber* covers the posterior surface of the posterior elastic lamina, is reflected on to the front of the iris, and also lines the spaces of the angle of the iris; it consists of a layer of polygonal, flattened, nucleated cells.

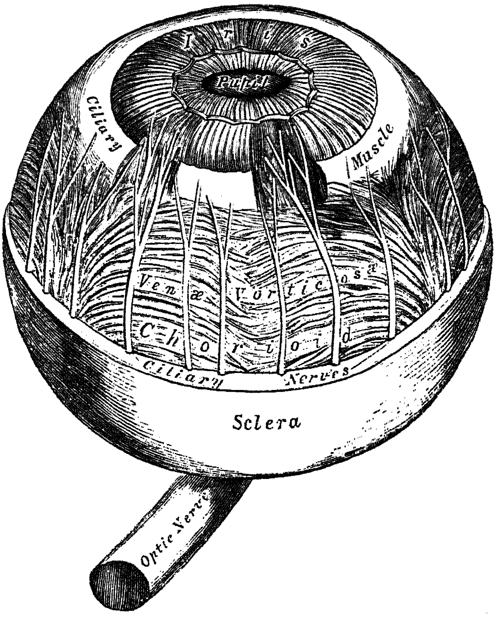
Vessels and Nerves.—The cornea is a non-vascular structure, the capillary vessels of the conjunctiva and sclera ending in loops at its circumference. Lymphatic vessels have not yet been demonstrated in it, but are probably represented by the channels in which the nerves run; these channels are lined by an endothelium. The *nerves* are numerous and are derived from the ciliary nerves. Around the periphery of the cornea they form an *annular plexus,* from which fibres enter the substantia propria. They lose their medullary sheaths and ramify throughout the substantia propria in a delicate network, and their terminal filaments form a firm and closer plexus beneath the corneal epithelium. This is termed the *subepithelial plexus,* and from it fine, varicose fibrils are given off which ramify between the epithelial cells, forming an *intra-epithelial plexus.*

II. The Vascular Tunic (figs. 951, 953, 954)

The vascular tunic of the eye is formed from behind forwards by the chorioid, the ciliary body, and the iris.

The chorioid covers the inner surface of the sclera, and extends as far forwards as the ora serrata of the retina. The ciliary body connects the chorioid with the circumference of the iris. The iris is a circular diaphragm behind the cornea, and presents near its centre a rounded aperture, the *pupil*.

Fig. 951.—The chorioid and iris. (Enlarged.)



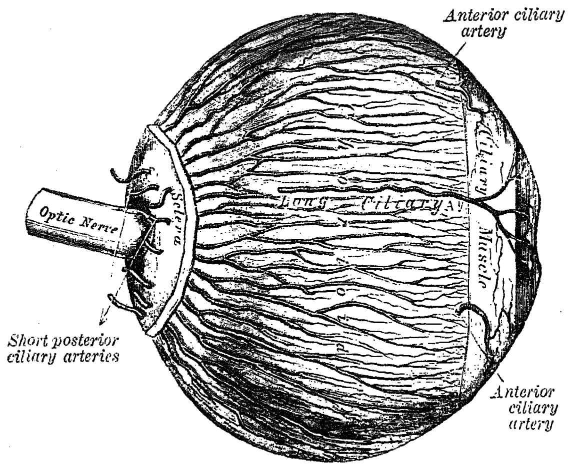
The **chorioid** is a thin, highly vascular membrane, of a dark brown or chocolate colour, investing the posterior five-sixths of the globe; it is pierced behind by the optic nerve, and in this situation is firmly adherent to the sclera. It is thicker behind than in front. Its outer surface is loosely connected with the sclera by the lamina suprachorioidea; its inner surface is attached to the pigmented layer of the retina.

Structure.—The chorioid consists mainly of a dense capillary plexus, and of small arteries and veins carrying blood to and from it. On its external surface is a thin membrane, the *lamina suprachorioidea,* composed of delicate non-vascular lamellæ, each lamella consisting of a network of fine elastic fibres among which are branched pigment-cells. The spaces between the lamellæ are lined by endothelium, and open freely into the perichorioidal lymph-space, which, in its turn, communicates with the perischeral space at the points where the vessels and nerves are transmitted through the sclera.

Internal to this lamina is the *chorioid proper*, consisting of two layers: an outer, composed of small arteries and veins, with pigment-cells interspersed between

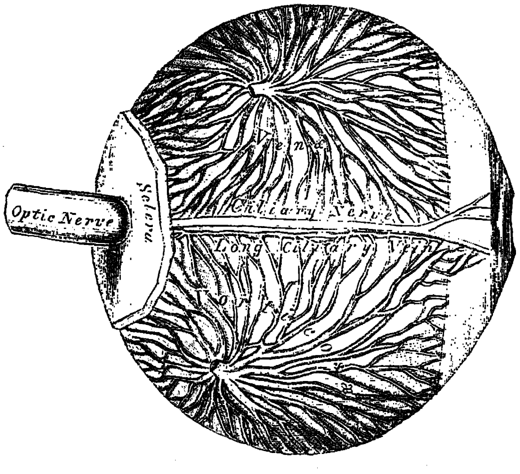
them; and an inner, consisting of a capillary plexus. The *outer layer* or *lamina vasculosa* consists, in part, of the larger branches of the short posterior ciliary arteries which run forwards between the veins before they bend inwards to end in the capillaries, but is formed principally of veins, named, from their arrangement, the *venæ vorticosæ* (fig. 953): these converge to four or five equidistant trunks which pierce the sclera about midway between the sclerocorneal junction and the entrance of the optic nerve. Interspersed between the vessels are dark star-shaped pigment-cells, the processes of which communicate with those of neighbouring cells, and form a delicate network or stroma, which loses its pigmentary character towards the inner surface of the chorioid. The *inner layer* or *lamina choriocapillaris* consists of an exceedingly fine capillary plexus, formed by the short ciliary vessels; the network is closer and finer in the posterior than in the anterior part of the chorioid. About 1·25 cm. behind the cornea its meshes become larger, and are continuous with those of the ciliary processes. These two laminæ are connected by a *stratum intermedium* consisting of fine elastic fibres. On the inner surface of the lamina choriocapillaris is a very thin, structureless, or faintly fibrous membrane, called the *lamina basalis*; it is closely connected with the stroma of the chorioid, and separates it from the pigmentary layer of the retina.

Fig. 952.—The arteries of the chorioid and iris. The greater part of the sclera has been removed. (Enlarged.)



Tapetum.—This name is applied to the outer and posterior part of the chorioid, which in many animals presents an iridescent appearance.

Fig. 953.—The veins of the chorioid. (Enlarged.)



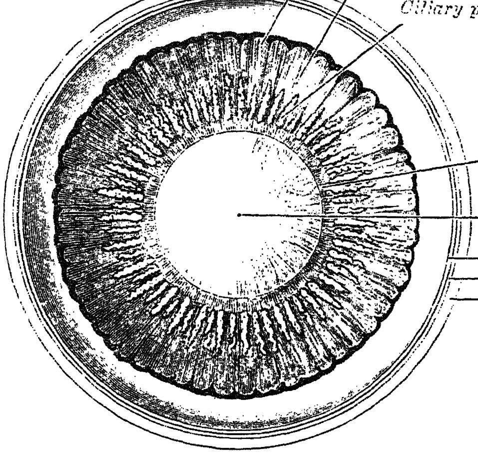
The **ciliary body** comprises the orbicularis ciliaris, the ciliary processes, and the Ciliaris muscle.

The *orbicularis ciliaris* is a zone of about 4 mm. in width, directly continuous with the anterior part of the chorioid; it presents numerous ridges arranged in a radial manner, but has no lamina choriocapillaris.

The *ciliary processes* are formed by the inward folding of the various layers of the chorioid (i.e. the chorioid proper and the lamina basalis), and are received between corresponding foldings of the suspensory ligament of the lens. They are arranged in a circle, and form a sort of frill behind the iris, round the margin of the lens (fig. 954). They vary from sixty to eighty in number, lie side by side, and may be divided into large and small processes; the former are about 2·5 mm. long, and the latter, consisting of about one-third of the entire number, are situated in the spaces between them, but without regular alternation. Each is attached by its periphery to three

or four of the ridges of the orbicularis ciliaris and is continuous with the layers of the chorioid: their opposite extremities are free and rounded, and are directed towards the posterior chamber of the eyeball and circumference of the lens. In front, they are continuous with the periphery of the iris. Their posterior surfaces are connected with the suspensory ligament of the lens.

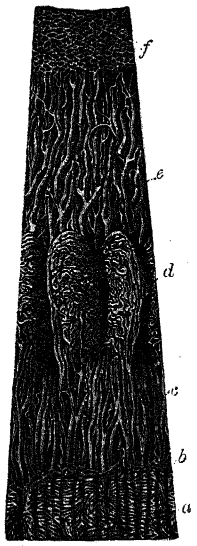
Fig. 954.—The interior of the anterior half of the bulb of the eye.



The ciliary processes (figs. 954, 955) are similar in structure to the chorioid, but the vessels are larger and have chiefly a longitudinal direction. Their posterior surfaces are covered by the *pars ciliaris retinæ*, continued forwards from the retina, and consisting of an outer layer of cubical pigment-cells, and an inner layer of columnar cells which are not pigmented. In the stroma of the ciliary processes there are also stellate pigment-cells, but these are not so numerous as in the chorioid itself.

The *Ciliaris muscle* consists of unstriped fibres: it forms a greyish, semitransparent, circular band, about 6 mm. broad, on the outer surface of the fore-part of the chorioid. It consists of meridional and circular fibres. The *meridional* fibres, much the more numerous, arise from the posterior margin of the scleral spur (p. 995); they run backwards, and are attached to the ciliary processes and orbicularis ciliaris. The *circular* fibres are internal to the meridional ones, and in a meridional section appear as a triangular zone behind the filtration angle and close to the circumference of the iris; they are well developed in hypermetropic, but are rudimentary or absent in myopic, eyes. The Ciliaris muscle is the chief agent in accommodation, i.e. in adjusting the eye to the vision of near objects. When it contracts, it draws forwards the ciliary processes, relaxes the suspensory ligament of the lens, and thus allows the lens to become more convex.

Fig. 955.—The vessels of the chorioid, ciliary processes, and iris, of a child. (Arnold.) × 10.

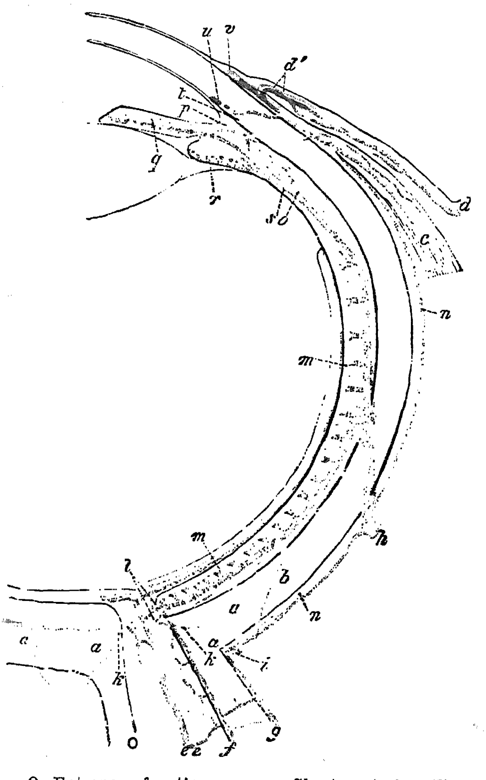


a. Capillary network of the anterior part of the chorioid, ending at *b*, the ora serrata. *c*. Arteries supplying the ciliary processes *d*, and passing into the iris *e*. *f*. The capillary network close to the pupillary margin of the iris.

The **iris** has received its name from the various colours it presents in different individuals. It is a thin, circular, contractile disc, suspended in the aqueous humour between the cornea and the crystalline lens, and perforated a little to the nasal side of its centre by a circular aperture, the *pupil*. Its periphery is continuous with the ciliary body, and is also connected with the posterior elastic lamina of the cornea by means of the pectinate ligament; its flattened surfaces look forwards and backwards, the anterior towards the cornea, the posterior towards the ciliary processes and

lens. The iris divides the space between the lens and the cornea into an anterior and a posterior chamber (fig. 948). The *anterior chamber* of the eye is bounded in front by the posterior surface of the cornea, behind by the front of the iris, and, opposite the pupil, by the central part of the front of the lens. The *posterior chamber* is a narrow chink behind the iris, and in front of the lens and its suspensory ligament. In the adult the two chambers communicate through the pupil, but in the fœtus up to the seventh month they are separated by the *membrana pupillaris* (p. 1001).

FIG. 956.—A diagrammatic representation of the course of the vessels of the eye. Horizontal section. (Leber.) Arteries and capillaries red; veins blue.



O. Entrance of optic nerve. *a.* Short posterior ciliary arteries. *b.* Long posterior ciliary arteries. *c.* Anterior ciliary vessels. *d.* Posterior conjunctival vessels. *d.** Anterior conjunctival vessels. *e.* Central vessels of the retina. *f.* Vessels of the inner sheath of the optic nerve. *g.* Vessels of the outer sheath. *h.* Vorticose veins. *i.* Short posterior ciliary vein. *k.* Branches of the short posterior ciliary arteries to the optic nerve. *l.* Anastomosis of chorioidal vessels with those of optic nerve. *m.* Choriocapillaris. *n.* Episcleral vessels. *o.* Recurrent artery of the chorioid. *p.* Circulus iridis major (in section). *q.* Vessels of iris. *r.* Vessels of ciliary process. *s.* Branch from ciliary muscle to vorticose vein. *t.* Branch from ciliary muscle to anterior ciliary vein. *u.* Sinus venosus scleræ. *v.* Capillary loop at margin of cornea.

Structure.—The iris is composed of the following structures:

1. In front is a layer of flattened endothelial cells placed on a delicate hyaline basement-membrane. This layer of cells is continuous with the endothelium covering the posterior elastic lamina of the cornea, and in individuals with dark-coloured irises the cells contain pigment-granules.

2. The *stroma* of the iris consists of connective tissue fibres and cells. A few fibres at the circumference of the iris have a circular direction; but the majority are arranged radially, forming, by their interlacement, delicate meshes, in which the vessels and nerves are contained. Interspersed between the bundles of connective tissue are numerous branched cells with fine processes. In dark eyes many of these cells contain pigment-granules, but in blue eyes and the eyes of albinos they are unpigmented.

3. The *muscular fibres* are involuntary, and consist of circular and radiating fibres. The *circular fibres* form the Sphincter pupillæ; they are arranged in a band about 1 mm. wide which surrounds the margin of the pupil, towards the posterior surface of the iris; those near the free margin of the band are closely aggregated; those near the periphery are somewhat separated and form incomplete circles. The *radiating fibres* form the Dilatator pupillæ and lie close to the posterior surface of the iris; they converge from the circumference towards the centre, and blend with the circular fibres near the margin of the pupil.

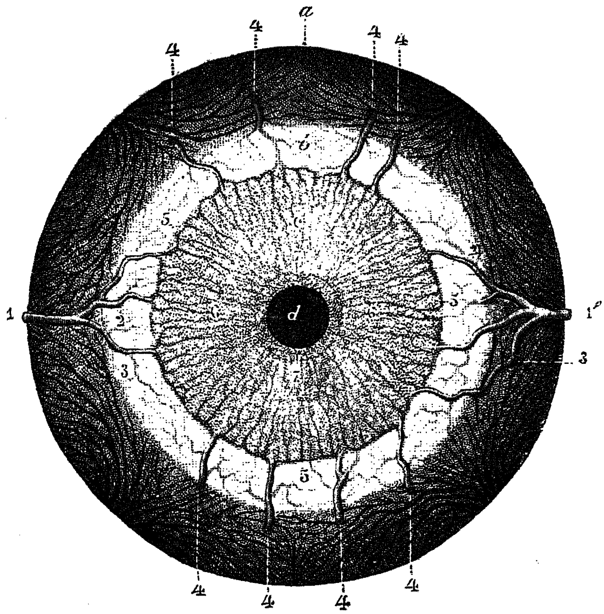
4. The posterior surface of the iris is of a deep purple tint, being covered by two layers of pigmented epithelial cells, continuous at the periphery of the iris with the pars ciliaris retinæ. This pigmented epithelium is named the *pars iridica retinæ* or, from the resemblance of its colour to that of a ripe grape, the *uvea*.

The colour of the iris is produced by the reflection of light from dark pigment-cells underlying a translucent tissue, and is therefore determined by the amount of the pigment and its distribution throughout the texture of the iris. The number and the situation of the pigment-cells differ in different irises. In the albino pigment is absent; in the various shades of blue eyes the pigment-cells are confined to the posterior surface of the iris, whereas in grey, brown, and black eyes pigment

is found also in the cells of the stroma and in those of the endothelium on the front of the iris.

Vessels and Nerves.—The *arteries of the iris* are derived from the long posterior and the anterior ciliary arteries, and from the vessels of the ciliary processes (p. 627). Each of the two long ciliary arteries, on reaching the attached margin of the iris, divides into an upper and a lower branch; these anastomose with corresponding branches of the artery from the opposite side and with the anterior ciliary arteries and form a vascular circle (*circulus arteriosus major*). From this circle vessels converge to the free margin of the iris, and there communicate and form a second circle (*circulus arteriosus minor*) (figs. 956, 957).

Fig. 957.—The iris, viewed from in front, with its circulus arteriosus major and circulus arteriosus minor. (Testut.)



a. Chorioid. *b.* Ciliaris muscle. *c.* Iris. *d.* Pupil. 1 and 1′. The two long ciliary arteries with 2, their ascending branches of bifurcation; 3, their descending branches of bifurcation. 4. The anterior ciliary arteries. 5. Circulus major; 6, its branches radiating through the iris. 7. Circulus minor around the pupil.

The *nerves of the chorioid and iris* are the long and short ciliary nerves; the former are branches of the nasociliary nerve, the latter of the ciliary ganglion. They pierce the sclera around the entrance of the optic nerve, run forwards in the perichorioidal space, and supply the blood-vessels of the chorioid and the ciliary muscle. After reaching the iris they form a plexus around its attached margin; from this are derived non-medullated fibres which end in the Sphincter and Dilatator pupillæ. Other fibres from the plexus end in a network on the anterior surface of the iris. The fibres derived through the parasympathetic root of the ciliary ganglion from the oculomotor nerve supply the Sphincter pupillæ and the Ciliaris muscle; the sympathetic fibres in the long ciliary nerves supply the Dilatator pupillæ.

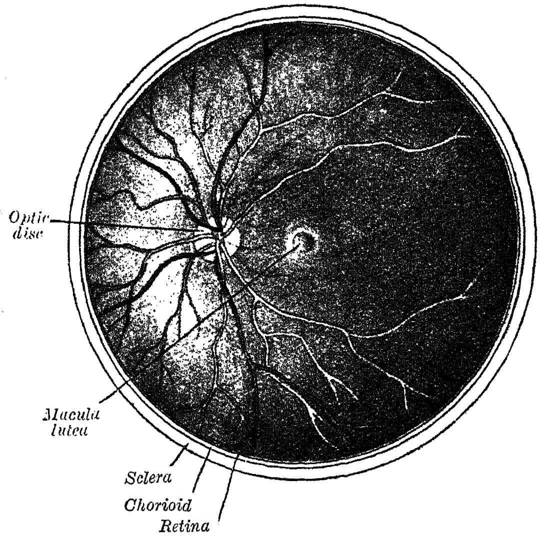
Membrana pupillaris.—In the fœtus, the pupil is closed by a delicate vascular membrane, the *membrana pupillaris*, which divides the space in which the iris is suspended into two separate chambers. The vessels of this membrane are partly derived from those of the margin of the iris and partly from those of the capsule of the lens; they end in loops a short distance from the centre of the membrane, which is thus left free from blood-vessels. About the sixth month of fœtal life the membrane begins to disappear by absorption from the centre towards the circumference, and at birth only a few fragments are present; in exceptional cases it persists.

III. The Retina

The **retina** is a delicate nervous membrane, in which the images of external objects are received. Its outer surface is in contact with the chorioid; its inner with the hyaloid membrane of the vitreous body. Posteriorly, it is

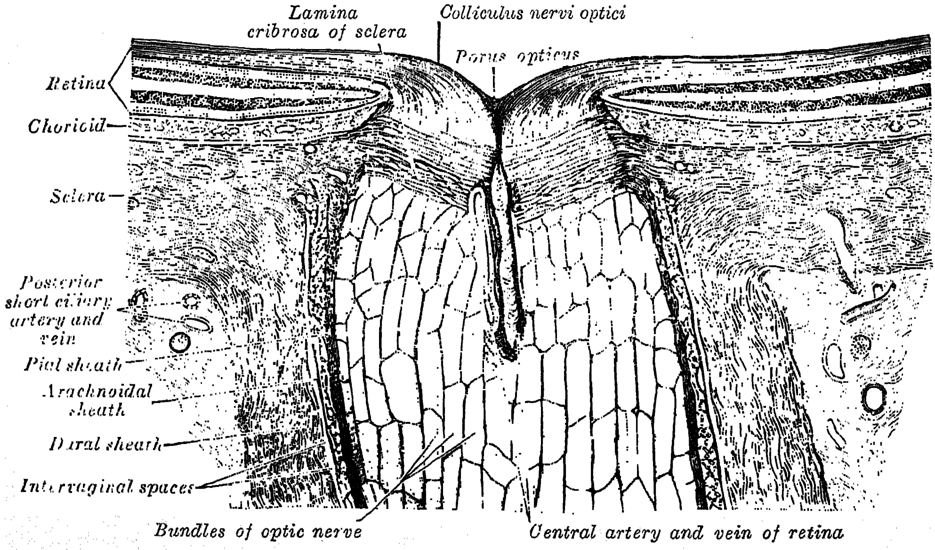
continuous with the optic nerve; it gradually diminishes in thickness from behind forwards, and just behind the ciliary body, it presents a jagged margin, the *ora serrata*. Here the nervous tissues of the retina end, but a thin prolongation of the membrane extends forwards over the back of the ciliary processes and iris, forming the *pars ciliaris retinæ* and *pars iridica retinæ* or *uvea*, already referred to. This forward prolongation consists of the pigmentary layer of the retina together with a stratum of columnar epithelium; in the pars iridica retinæ both layers of epithelium are cubical and pigmented. The retina is soft, translucent, and of a purple tint in the fresh state, owing to the presence of a colouring material named *rhodopsin* or *visual purple*; but it soon becomes clouded, opaque, and bleached when exposed to sunlight. Near the centre of the posterior part of the retina is an oval yellowish area the *macula lutea*, where the visual sense is most perfect; in the macula is a central depression, the *fovea centralis* (fig. 958). At the fovea centralis the retina is exceedingly thin, and the dark colour of the chorioid is distinctly seen through it. About 3 mm. to the nasal side of the macula lutea is the entrance of the optic nerve (*optic disc*) which has a diameter of about 1·5 mm. The circumference of the disc is slightly raised to form the

FIG. 958.—The interior of the posterior half of the bulb of the left eye.



The veins are darker in appearance than the arteries.

FIG. 959.—A horizontal section through the terminal portion of the optic nerve and its entrance into the bulb of the eye. (From Toldt's 'Atlas,' published by Messrs. Rebman, Ltd., London.)

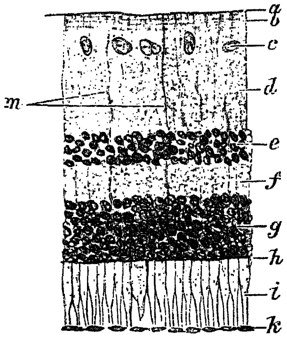


papilla of the optic nerve, while the central part presents a depression, named the *excavation* of the optic nerve (optic cup). The centre of the disc is pierced by the central artery and vein of the retina. The optic disc is insensitive to light, and is termed the 'blind spot.'

Structure (figs. 960, 961).—The retina consists of an outer pigmented layer and an inner nervous stratum or retina proper.

The **pigmented layer** is a single stratum of cells. When viewed from the outer surface these cells are smooth and hexagonal in shape; when seen in section each cell consists of an outer non-pigmented part containing a large oval nucleus, and an inner pigmented portion which extends as a series of straight thread-like processes between the rods (fig. 961), the amount of pigment between the rods being greater when the eye has been exposed to light. In the eyes of albinos the cells of this layer are destitute of pigment.

Fig. 960.—A section through the retina. (Magnified.)



a. Membrana limitans interna. *b.* Stratum opticum. *c.* Ganglionic layer. *d.* Inner plexiform layer. *e.* Inner nuclear layer. *f.* Outer plexiform layer. *g.* Outer nuclear layer. *h.* Membrana limitans externa. *i.* Layer of rods and cones. *k.* Pigmented layer. *m.* Fibres of Müller.

Retina proper.—The nervous structures of the retina proper are supported by a series of non-nervous or sustentacular fibres, and, when examined microscopically by means of sections made perpendicular to the surface of the retina, are found to consist of seven layers, named from within outwards as follows:

1. Stratum opticum.
2. Ganglionic layer.
3. Inner plexiform layer.
4. Inner nuclear layer.
5. Outer plexiform layer.
6. Outer nuclear layer.
7. Layer of rods and cones.

1. The *stratum opticum* or *layer of nerve-fibres* is formed by the expansion of the fibres of the optic nerve; it is thickest near the optic disc, gradually diminishing towards the ora serrata. As the nerve-fibres pass through the lamina cribrosa scleræ (p. 994), they lose their medullary sheaths and are continued onwards through the chorioid and retina as simple axis-cylinders. When they reach the internal surface of the retina they radiate from their point of entrance over this surface, grouped in bundles which communicate with one another and form an intricate network. Most of the fibres are centripetal, and are the continuations of the axis-cylinder processes of the cells of the ganglionic layer, but a few are centrifugal; these originate in the brain and ramify in the inner plexiform and inner nuclear layers of the retina, where they end in branches.

2. The *ganglionic layer* consists of a single layer of large nerve-cells, except in the macula lutea, where there are several strata. The cells are somewhat flask-shaped, the rounded internal surface of each resting on the stratum opticum, and sending off an axon which is prolonged into it. From the opposite end numerous dendrites extend into the inner plexiform layer, where they form flattened arborisations at different levels. The ganglion-cells vary much in size, and the dendrites of the smaller ones as a rule arborise in the inner plexiform layer as soon as they enter it; while those of the larger cells ramify close to the inner nuclear layer.

3. The *inner plexiform layer* is made up of a dense reticulum of minute fibrils formed by the interlacement of the dendrites of the ganglion-cells with the processes of the cells of the inner nuclear layer; within this reticulum a few branched cells are imbedded.

4. The *inner nuclear layer* is made up of a number of closely packed cells, of which there are three varieties, viz. bipolar cells, horizontal cells, and amacrine cells.

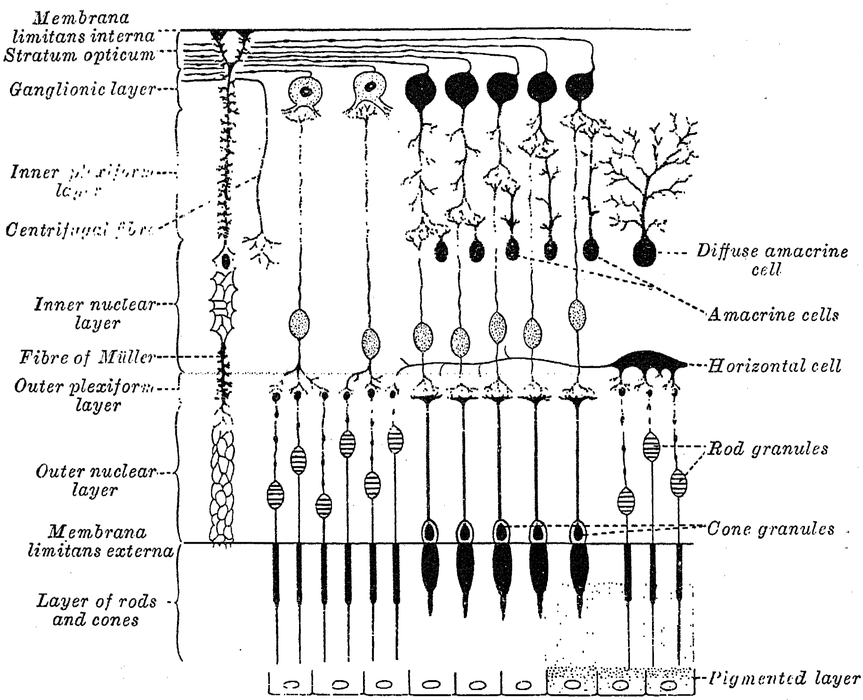
The *bipolar cells*, by far the most numerous, are divisible into rod- and cone-bipolars. They are round or oval in shape, and each is prolonged into an inner and an outer process. The inner processes of the *rod-bipolars* run through the inner plexiform layer and arborise around the outer parts of the cell-bodies of the ganglionic layer; their outer processes end in the outer plexiform layer in tufts of fibrils around the button-like ends of the inner processes of the rod-granules. The inner processes of the *cone-bipolars* ramify in the inner plexiform layer in contact with the dendrites of the ganglionic cells; their outer processes pass into

the outer plexiform layer, where they divide and form arborisations with the expanded foot-plates of the inner processes of the cone-granules.

The *horizontal cells* lie in the outer part of the inner nuclear layer and possess somewhat flattened cell-bodies. Their dendrites divide into numerous branches in the outer plexiform layer, while their axons run horizontally for some distance and finally ramify in the same layer.

The *amacrine cells* are placed in the inner part of the inner nuclear layer, and were so named under the supposition that they were destitute of axons. It is now known that some, at least, possess axons. Their dendrites undergo extensive ramification in the inner plexiform layer.

Fig. 961.—A plan of the retinal neurons. (After Ramón y Cajal.)



5. The *outer plexiform layer* is much thinner than the inner; but, like it, consists of a dense network of minute fibrils derived from the processes of the horizontal cells, and the outer processes of the rod- and cone-bipolar cells of the preceding layer, which arborise around the enlarged ends of the rod-fibres and the branched foot-plates of the cone-fibres.

6. The *outer nuclear layer*.—Like the inner nuclear layer, this contains several strata of oval cells; they are of two kinds, viz. rod-granules and cone-granules, the former being connected with the rods, the latter with the cones, of the next layer. The *rod-granules* are much the more numerous, and are placed at different levels throughout the layer; in some animals they present a cross-striped appearance. A fine process is prolonged from either extremity of each cell: the outer process is continuous with a rod of the layer of rods and cones; the inner process ends in the outer plexiform layer in an enlarged extremity, and is imbedded in the tuft into which the outer processes of the rod-bipolar cells break up; in its course it presents numerous varicosities. The *cone-granules*, fewer in number than the rod-granules, are placed close to the membrana limitans externa, through which they are continuous with the cones of the layer of rods and cones. Each contains a spheroidal nucleus which almost completely fills the granule. From the inner extremity of each cone-granule a thick process passes into the outer plexiform layer, and there expands into a pyramidal enlargement or foot-plate, from which are given off numerous fine fibrils that come in contact with the outer processes of the cone-bipolars.

divides it gives off an *interosseous branch* which supplies the metatarsophalangeal joint of the great toe and sends a filament to the first Interosseus dorsalis muscle.

The **superficial peronæal nerve** (musculocutaneous nerve) (fig. 922) begins at the bifurcation of the common peronæal nerve, passes forwards between the Peronæi and the Extensor digitorum longus, pierces the deep fascia at the lower one-third of the leg, and divides into a medial and an intermediate dorsal cutaneous nerve. In its course between the muscles, it gives off muscular branches to the Peronæus longus and Peronæus brevis, and filaments to the skin of the lower part of the leg.

The *medial dorsal cutaneous nerve* passes in front of the ankle-joint, and divides into two dorsal digital branches, one of which supplies the medial side of the great toe, the other, the adjacent sides of the second and third toes. It communicates with the saphenous nerve and with the deep peronæal nerve (fig. 920).

The *intermediate dorsal cutaneous nerve*, the smaller, passes along the lateral part of the dorsum of the foot, and divides into dorsal digital branches, which supply the contiguous sides of the third and fourth, and of the fourth and fifth toes. It also supplies the skin of the lateral side of the ankle, and communicates with the lateral dorsal cutaneous nerve (fig. 920).

The branches of the superficial peronæal nerve supply the skin of the dorsal surfaces of all the toes excepting the lateral side of the little toe and the adjoining sides of the great and second toes, the former being supplied by the lateral dorsal cutaneous branch of the sural nerve, and the latter by the medial branch of the deep peronæal nerve. Frequently some of the lateral branches of the superficial peronæal are absent, and their places are then taken by branches of the lateral dorsal cutaneous nerve.

The Pudendal Plexus

The **pudendal plexus** (figs. 923, 924) is not sharply marked off from the sacral plexus, and as a consequence some of its branches arise in conjunction with those of the sacral plexus. It lies on the posterior wall of the pelvic cavity and is usually formed by parts of the anterior divisions of the second, third, and fourth sacral nerves, the anterior division of the fifth sacral nerve, and the anterior division of the coccygeal nerve.

It gives off the following branches :

Perforating cutaneous	2, 3 S.
Pudendal	2, 3, 4 S.
Visceral	3, 4 S.
Muscular	4 S.
Anococcygeal	4, 5 S. and Cocc.

The **perforating cutaneous nerve** usually arises from the posterior surfaces of the second and third sacral nerves. It pierces the lower part of the sacrotuberous ligament, and, winding round the inferior border of the Glutæus maximus, supplies the skin covering the medial and lower parts of that muscle.

The perforating cutaneous nerve may arise from the pudendal nerve or it may be absent : in the latter case its place may be taken by a branch from the posterior femoral cutaneous nerve or by a branch from the third and fourth, or fourth and fifth, sacral nerves.

The **pudendal nerve** (pudic nerve) derives its fibres from the second, third, and fourth sacral nerves. It passes between the Piriformis and Coccygeus muscles and leaves the pelvis through the lower part of the greater sciatic foramen. It then crosses the spine of the ischium on the medial side of the internal pudendal vessels, and passes through the lesser sciatic foramen. It accompanies the internal pudendal vessels along the lateral wall of the ischiorectal fossa in *Alcock's canal*, and after giving off the inferior hæmorrhoidal nerve, it divides into the perinæal nerve, and the dorsal nerve of the penis or clitoris.

The *inferior hæmorrhoidal nerve* occasionally arises directly from the sacral plexus ; it crosses the ischiorectal fossa with the inferior hæmorrhoidal vessels,

The Refracting Media of the Eye

The refracting media of the eye are the aqueous humour, the vitreous body, and the crystalline lens.

I. The Aqueous Humour

The **aqueous humour** fills the anterior and posterior chambers of the bulb of the eye (p. 1000). It is small in quantity, has an alkaline reaction, and is mainly a dilute watery solution of chloride of sodium. It is secreted by the ciliary processes into the posterior chamber, and escapes from the filtration angle of the anterior chamber through the spaces of the angle of the iris (spaces of Fontana) and the sinus venosus scleræ (canal of Schlemm) into the anterior ciliary veins.

II. The Vitreous Body

The **vitreous body** (fig. 948) occupies about four-fifths of the bulb of the eye. It fills the concavity of the retina, and is hollowed in front, forming a deep concavity, the *hyaloid fossa*, for the reception of the lens. It is transparent, of the consistence of thin jelly, and is enclosed in a delicate transparent membrane, the *hyaloid membrane.* It has been supposed by Hannover, that from the surface of the hyaloid membrane numerous thin lamellæ are prolonged inwards in a radiating manner, forming spaces in which the jelly is contained. In the adult, these lamellæ cannot be detected even after careful microscopical examination in the fresh state, but in preparations hardened in weak chromic acid it is possible to make out a distinct lamellation at the periphery of the vitreous body. Running forwards through the vitreous body from the entrance of the optic nerve to the posterior surface of the lens, is the *hyaloid canal,* filled with lymph and lined by a prolongation of the hyaloid membrane. In the embryonic vitreous body this canal conveyed the arteria hyaloidea from the central artery of the retina to the back of the lens.

The vitreous body consists of 98·6 per cent. of water, with some salts, and a little protein.

The *hyaloid membrane* envelops the vitreous body. The portion in front of the ora serrata is thickened by the accession of radial fibres and is termed the *zonula ciliaris* or *zonule of Zinn.* Here it presents a series of radially arranged furrows, in which the ciliary processes are accommodated and to which they adhere, as is shown by the fact that when they are removed some of their pigment remains attached to the zonula. The zonula ciliaris splits into two layers, one of which is thin and lines the hyaloid fossa of the vitreous body; the other, named the *suspensory ligament of the lens,* is thicker, and passes over the ciliary body to be attached to the capsule of the lens a short distance in front of its equator. Scattered and delicate fibres are also attached to the region of the equator itself. This ligament retains the lens in position, and is relaxed by the contraction of the meridional fibres of the Ciliaris muscle, so that the lens is allowed to become more convex. Behind the suspensory ligament there is a sacculated canal, the *spatia zonularia* or *canal of Petit,* which encircles the equator of the lens; it can be easily inflated through a fine blowpipe inserted under the suspensory ligament.

No blood-vessels penetrate the vitreous body; so that its nutrition must be carried on by the vessels of the retina and ciliary processes, situated upon its exterior.

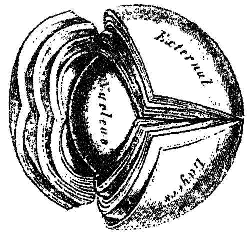
III. The Crystalline Lens

The **crystalline lens** (fig. 948), enclosed in its capsule, is situated immediately behind the iris, in front of the vitreous body, and is encircled by the ciliary processes, which slightly overlap its margin.

The *capsule of the lens* is a transparent, structureless membrane which closely surrounds the lens, and is thicker in front than behind. It is brittle

but highly elastic, and when ruptured the edges roll up with the outer surface innermost. The lens rests, behind, in the hyaloid fossa on the fore-part of the vitreous body; in front, it is in contact with the free border of the iris, but recedes from it at the circumference, thus forming the posterior chamber of the eye; it is retained in its position chiefly by the suspensory ligament already described.

Fig. 962.—The crystalline lens, hardened and divided. (Enlarged.)



The *lens* is a transparent, biconvex body, the convexity of its anterior being less than that of its posterior surface. The central points of these surfaces are termed respectively the *anterior* and *posterior poles*; a line connecting the poles constitutes the *axis* of the lens, while the marginal circumference is termed the *equator*.

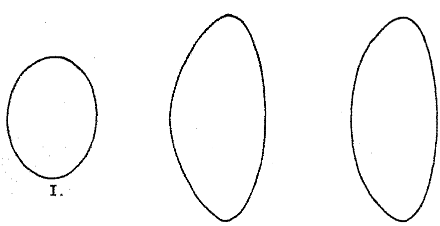
Structure.—The lens is made up of soft cortical substance and a firm, central part, the nucleus (fig. 962). Faint lines (radii lentis) radiate from the poles to the equator. In the adult there may be six or more of these lines, but in the fœtus there are only three, and these diverge from each other at angles of 120° (fig. 963); on the anterior surface one line ascends vertically and the other two diverge downwards; on the posterior surface one line descends vertically and the other two diverge upwards. These lines correspond with the free edges of an equal number of septa composed of an amorphous substance, which dip into

Fig. 963.—A diagram showing the direction and arrangement of the radiating lines on the front and back of the fœtal lens. A. On the front. B. On the back.

A. B.

the substance of the lens. When the lens has been hardened it is seen to consist of a series of concentrically arranged laminæ, each of which is interrupted at the septa referred to. Each lamina is built up of a number of ribbon-like lens-fibres, the edges of which are more or less serrated—the serrations fitting between those of neighbouring fibres, while the ends of the fibres come into apposition at the septa. The fibres run in a curved manner from the septa on the anterior surface to those on the posterior surface. No fibres pass from pole to pole; they are arranged in such a way that those which begin near the pole on one surface of the lens end near the peripheral extremity of the plane on the other, and vice versa. The fibres of the outer layers of the lens are nucleated, and together form a nuclear layer, most distinct towards the equator. The anterior surface of the lens is covered by a layer of transparent, nucleated columnar epithelium. At the equator the cells become elongated, and their gradual transition into lens-fibres can be traced (fig. 965).

Fig. 964.—Profile views of the lens at different periods of life.



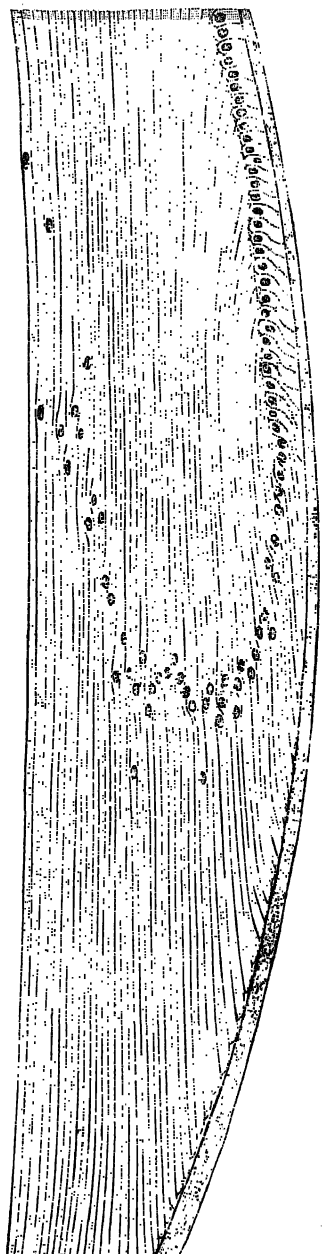
1. 2. 3.

1. In the fœtus. 2. In adult life. 3 In old age.

In the fœtus, the lens is nearly spherical, and has a slightly reddish tint; it is soft, and breaks down readily on the slightest pressure. A small branch (arteria hyaloidea) from the arteria centralis retinæ runs forwards through the vitreous

body to the posterior part of the capsule of the lens, where its branches radiate, forming a plexiform network which covers the posterior surface of the capsule, and is continuous round the margin of the capsule with the vessels of the pupillary membrane and with those of the iris. *In the adult*, the lens is colourless, transparent, firm in texture, and devoid of vessels. *In old age*, it becomes flattened on both surfaces, slightly opaque, of an amber tint, and increased in density (fig. 964).

Fig. 965.—A section through the margin of the lens, showing the transition of the columnar epithelium into the lens-fibres. (Babuchin.)



Vessels and Nerves.—The *arteries* of the bulb of the eye are the long, short, and anterior ciliary arteries, and the arteria centralis retinæ. They have already been described (p. 627).

The *ciliary veins* are seen on the outer surface of the chorioid, and are named, from their arrangement, the *venæ vorticosæ*; they converge to four or five equidistant trunks which pierce the sclera midway between the sclerocorneal junction and the porus opticus. Another set of veins accompanies the anterior ciliary arteries. All these veins open into the ophthalmic veins.

The *ciliary nerves* are derived from the nasociliary nerve and from the ciliary ganglion.

Applied Anatomy.—From a surgical point of view the cornea may be regarded as consisting of three layers: (1) an external epithelial layer, developed from the ectoderm, and continuous with the epithelial covering of the rest of the body, so that its lesions resemble those of the epidermis; (2) the cornea proper, derived from the mesoderm, and associated in its diseases with the fibrovascular structures of the body; and (3) the posterior elastic lamina with its endothelium, also derived from the mesoderm and having the characters of a serous membrane, so that inflammation of it resembles inflammation of the serous and synovial membranes of the body.

The cornea contains no blood-vessels except at its periphery, where numerous delicate loops, derived from the anterior ciliary arteries, may be demonstrated on its anterior surface. The rest of the cornea is nourished by lymph, which gains access to the proper substance of the cornea and the posterior layer through the spaces of the angle of the iris. This lack of a direct blood-supply renders the cornea very apt to inflame in the cachectic and ill-nourished. In cases of *granular lids*, there is a peculiar affection of the cornea, called *pannus*, in which the anterior layers of the cornea become vascularised, and a rich network of blood-vessels may be seen upon it; and in *interstitial keratitis* new vessels extend into the cornea, giving it a pinkish hue to which the term 'salmon patch' is applied. In cases of glaucoma the ciliary nerves may be pressed upon as they course between the chorioid and sclera, the cornea becoming anæsthetic.

The sclera has very few blood-vessels and nerves. As the blood-vessels approach the corneal margin the arrangement is peculiar. Some branches pass through the sclera to the ciliary body; others become superficial and lie in the episcleral tissue, and form arches by anastomosing with each other some little distance behind the corneal margin. From these arches numerous straight vessels are given off, which run forwards to the cornea, forming its marginal plexus. In inflammation of the sclera and episcleral tissue these vessels become conspicuous, and form a pinkish zone of straight vessels radiating from the corneal margin, commonly known as the *zone of ciliary injection.* In inflammation of the iris and ciliary body this zone is present, since the sclera speedily

becomes involved when these structures are inflamed. But in inflammation of the cornea the sclera is seldom much affected, though the two are structurally continuous. This would appear to be due to the fact, that the nutrition of the cornea is derived from a different source than that of the sclera. The sclera may be ruptured without any laceration of the conjunctiva, and the rupture usually occurs near the corneal margin. It may be complicated with lesions of adjacent parts—laceration of the chorioid, retina, iris, or suspensory ligament of the lens—and is then often attended with hæmorrhage into the anterior chamber, which marks the nature of the injury. In some cases the lens has escaped through the rent in the sclera. Wounds of the sclera are always dangerous, and are often followed by inflammation, suppuration, and by sympathetic ophthalmia.

One of the functions of the chorioid is to provide nutrition for the retina, and to convey vessels and nerves to the ciliary body and iris. Inflammation of the chorioid is therefore followed by grave disturbances in the nutrition of the retina, and is attended with early interference with vision. Its diseases bear a considerable analogy to those which affect the skin, and it is one of the places from which melanotic sarcomata may grow. These tumours contain a large amount of pigment in their cells, and originate only in those parts where pigment is naturally present.

The iris may be absent, either in part or altogether, as a congenital condition, and in some instances the pupillary membrane may persist though rarely as a complete structure. Again, the iris may be the seat of malformation, termed *coloboma*, which consists of a deficiency or cleft, clearly due in a great number of cases to an arrest in development. In these cases the cleft is found at the lower aspect, extending directly downwards from the pupil, and the gap frequently extends through the chorioid to the porus opticus. Wounds of the iris, especially if complicated with injury to the ciliary body, may be followed by serious consequences. If septic matter is introduced, and a suppurative inflammation is set up, complete loss of vision may result; and, what is perhaps of greater consequence, similar inflammatory changes may be set up in the sound eye. The iris is abundantly supplied with blood-vessels and nerves, and is very prone to become inflamed, and when inflamed, in consequence of the intimate relationship which exists between the vessels of the iris and chorioid, this latter tunic is very liable to participate in the inflammation. The iris is covered with epithelium, and partakes of the character of a serous membrane, and like these structures, is apt to pour out a plastic exudation when inflamed, and contract adhesions, either to the cornea in front (*synechia anterior*), or to the capsule of the lens behind (*synechia posterior*). In iritis the lens may become involved, and the condition known as secondary cataract may be set up.

The retina, with the exception of its pigment layer and its vessels, is perfectly transparent. In retinitis there is more or less dense opacity of its structure, and not infrequently extravasations of blood into its substance. Hæmorrhages may also take place into the retina, from rupture of a blood-vessel without inflammation. The retina may become detached from effusion of serum between it and the chorioid, or by blows on the eyeball; but detachment of the retina may occur without apparent cause in progressive myopia. Glioma, a form of sarcoma, is occasionally met with in the retina.

The lens has no blood-vessels, nerves, or connective tissue in its structure, and therefore is not subject to those morbid changes to which tissues containing these structures are liable. Opacities may occur from injury, senile changes, or malnutrition. These opacities give rise to *cataract*, of which the senile variety is the most common. They vary as to the part of the lens in which the opacity commences, and are classified accordingly, as nuclear, cortical, lamellar, anterior and posterior polar. Senile changes may take place in the lens, impairing its elasticity and rendering it harder than in youth, so that it loses its power of altering its curvature to suit the requirements of near vision. This condition is known as *presbyopia*. The lens may be dislocated or displaced by blows upon the eyeball; and its relations to surrounding structures altered by adhesions or the pressure of new growths.

There are two particular regions of the eye which require special notice: one of these is known as the 'filtration angle,' and the other as the dangerous 'area.' The *filtration angle* is the circumcorneal zone immediately in front of the iris. Here are situated the spaces of the angle of the iris, which communicate with the sinus venosus scleræ through which the chief transudation of fluid from the eye is believed to take place. If any obstruction to this transudation occur, increased intra-ocular tension is set up, and the disease known as *glaucoma* results. The *dangerous area of the eye* is the region in the neighbourhood of the ciliary body, and wounds or injuries in this situation are peculiarly dangerous; for inflammation of the ciliary body is apt to spread to many of the other structures of the eye, especially to the iris and chorioid, which are intimately connected with it by nervous and vascular supplies.

The Accessory Organs of the Eye

The accessory organs of the eye include the ocular muscles, the fasciæ, the eyebrows, the eyelids, the conjunctiva, and the lacrimal apparatus.

The Ocular Muscles

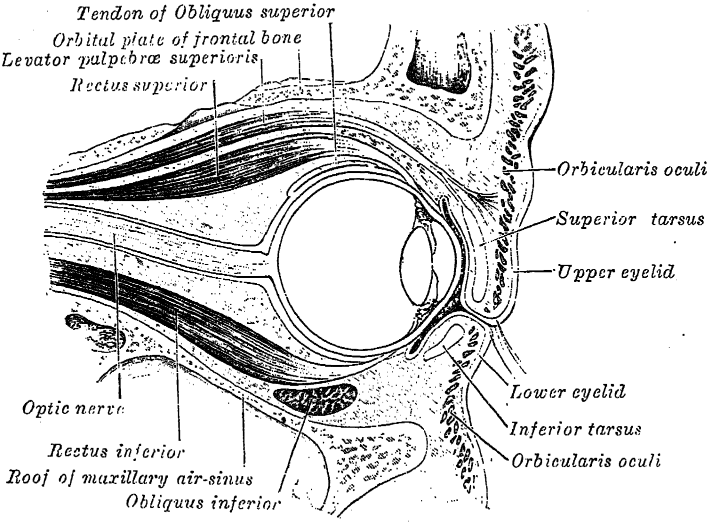
The ocular muscles are the :

Levator palpebræ superioris.	Rectus medialis.
Rectus superior.	Rectus lateralis.
Rectus inferior.	Obliquus superior.

Obliquus inferior.

The **Levator palpebrae superioris** (figs. 966, 967) is thin, and triangular in shape. It arises from the under surface of the small wing of the sphenoidal bone, above and in front of the optic foramen, from which it is separated

Fig. 966.—A sagittal section through the right orbital cavity.



by the origin of the Rectus superior. At its origin, it is narrow and tendinous but soon becomes broad and fleshy, the medial margin of the muscle being almost straight, while the lateral margin is concave. The muscle ends anteriorly in a wide aponeurosis which splits into two lamellæ. The uppermost fibres of the superficial lamella blend with the upper part of the orbital septum; the lowermost fibres are attached to the anterior surface of the superior tarsus, while the intermediate fibres radiate and pass through the overlying Orbicularis oculi to the skin of the upper eyelid. The deep lamella consists of non-striped muscular fibres and is known as *Müller's muscle* *; it is attached directly to the upper margin of the superior tarsus and is covered by conjunctiva on its inferior surface. The space between the superficial and deep lamellæ is termed the *pretarsal space* (fig. 967).

The fascial sheaths of the Levator palpebræ superioris and Rectus superior fuse. Where the two muscles separate to reach their insertions, the fascia between them forms a thick mass which is fixed to the superior conjunctival fornix and is described as an additional insertion of the Levator palpebræ superioris. When traced laterally the aponeurosis of the Levator palpebræ superioris passes between the upper and lower parts of the lacrimal gland, and is fixed to a tubercle on the zygomatic bone, just within the

* H. Müller also described a layer of non-striped muscle in the lower eyelid, where it unites the inferior tarsus to the Obliquus inferior.

taste-bud, and end in fine fibrils between the gustatory cells; other nerve-fibrils end between the epithelial cells which surround the taste-bud, but these are believed to be nerves of ordinary sensation and not gustatory.

Fig. 938.—A section through a taste-bud from the human tongue. Stained with hæmatoxylin and eosin. × 450.

Nerves of taste.—The chorda tympani nerve, derived from the sensory root of the facial nerve, and distributed with the lingual nerve, is the nerve of taste for the anterior two-thirds of the tongue; the glossopharyngeal is the nerve of taste for the posterior one-third of the tongue.

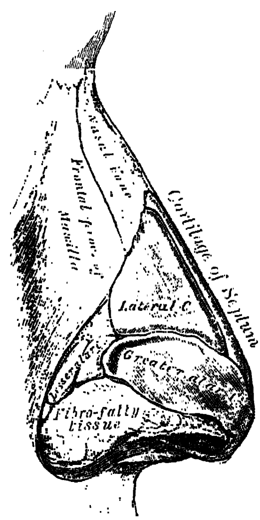
The Organ of Smell

The peripheral olfactory organ or organ of smell consists of two parts: an outer, the *external nose*, which projects from the centre of the face; and an internal, which is divided by a septum into *right* and *left nasal cavities*.

The **external nose** is pyramidal in form, and its upper angle or *root* is connected directly with the forehead; its free angle is termed the *apex*. Its *base* is perforated by two elliptical orifices, the *nares*, separated from each other by an antero-posterior septum, the *columna*. The lateral surfaces of the nose form, by their union in the middle line, the *dorsum nasi*, the direction of which varies considerably in different individuals; the upper part of the dorsum is supported by the nasal bones, and is named the *bridge*. The lateral surfaces end below in rounded eminences, the *alæ nasi*.

The framework of the external nose is composed of bones and hyaline cartilages. The *bony framework* occupies the upper part of the organ; it consists of the nasal bones, the frontal processes of the maxillæ, and the nasal part of the frontal bone. The *cartilaginous framework* consists of five large pieces, viz. the cartilage of the septum, the two lateral, and the two greater alar, cartilages (figs. 939, 940, 941). The various cartilages are connected to each other and to the bones by a tough fibrous membrane.

Fig. 939.—The cartilages of the right side of the nose. Lateral aspect.

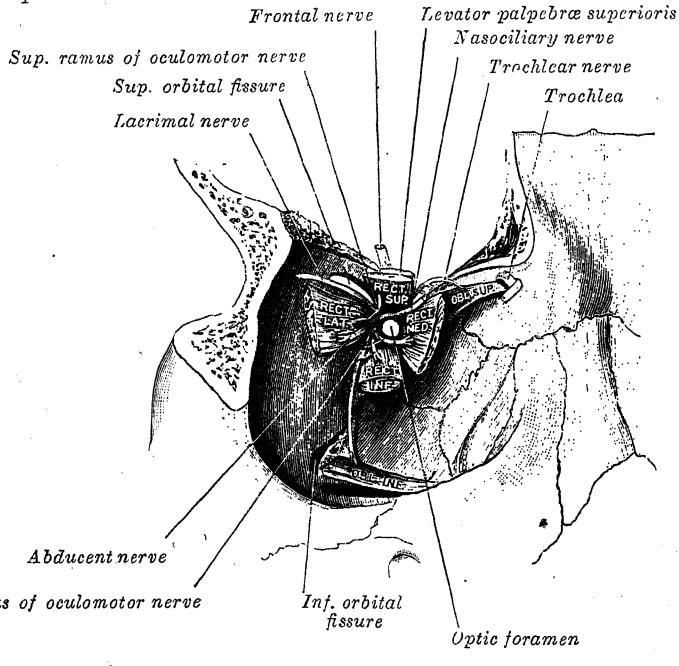


The *cartilage of the septum* (figs. 941, 942), somewhat quadrilateral in form, and thicker at its margins than at its centre, completes the separation between the nasal cavities in front. The upper part of its antero-superior margin is connected to the posterior border of the internasal suture; the middle part is continuous with the lateral cartilages; the lower part is attached to these cartilages by fibrous tissue. Its antero-inferior border is connected to the medial crura of the greater alar cartilages by fibrous tissue. Its postero-superior border is joined to the lamina perpendicularis of the ethmoidal bone, and its postero-inferior border is attached to the vomer and to the incisor crest of the maxillæ. The cartilage of the septum may extend backwards (especially in children) as a narrow process, the *sphenoidal process*, for some distance between the vomer and the lamina perpendicularis of the ethmoidal bone. The antero-inferior part of the nasal septum is freely movable, and hence is named the *septum mobile nasi*; it is not formed by the cartilage of the septum, but by the medial crura of the greater alar cartilages and by the skin.

The *lateral cartilage* (fig. 939) is situated below the inferior margin of the nasal bone, and is flattened, and triangular in shape. Its anterior margin is thicker than the posterior, and its upper part is continuous with the cartilage

closely adherent to the sheath of the optic nerve and to the surrounding periosteum; within it are (1) the optic foramen containing the optic nerve and ophthalmic artery, and (2) the medial end of the superior orbital fissure which transmits the two divisions of the oculomotor nerve, the nasociliary nerve, and the abducent nerve. The superior ophthalmic vein may pass through, or above, the ring; the inferior ophthalmic vein through, or below, the ring. Two specialised parts of this fibrous ring may be made out: a lower, the *ligament or tendon of Zinn*, which gives origin to the Rectus inferior, a part of the Rectus medialis, and the lower fibres of the Rectus lateralis; and an upper, sometimes termed the *superior tendon of Lockwood*, which gives origin to the Rectus superior, the other part of the Rectus medialis, and the upper fibres of the Rectus lateralis; a second small tendinous head of origin of the Rectus lateralis arises from the orbital surface of the great wing of the

FIG. 969.—A dissection showing the origins of the right ocular muscles, and the nerves entering the orbit through the superior orbital fissure. Anterior aspect.



sphenoidal bone, lateral to the annulus tendineus. Each muscle passes forward in the position implied by its name, to be inserted by a tendinous expansion into the sclera, about 6 mm. from the margin of the cornea.*

The **Obliquus oculi superior** is a fusiform muscle, placed at the upper and medial side of the orbit. It arises immediately above the optic foramen, superior and medial to the origin of the Rectus superior, and, passing forwards, ends in a round tendon, which plays in a fibrocartilaginous ring or pulley attached to the fovea trochlearis of the frontal bone. The contiguous surfaces of the tendon and ring are lubricated by a delicate mucous sheath. After traversing the pulley the tendon passes backwards, lateralwards, and downwards beneath the Rectus superior, to the lateral part of the bulb of the eye, and is inserted into the sclera, behind the equator of the eyeball, and between the Rectus superior and Rectus lateralis.

The **Obliquus oculi inferior** is a thin, narrow muscle, placed near the anterior margin of the floor of the orbit. It arises from the orbital surface of

* The average distances of the insertions of the Recti from the margin of the cornea are: Rectus medialis, 5·5 mm.; Rectus inferior, 6·5 mm.; Rectus lateralis, 6·9 mm.; Rectus superior, 7·7 mm.

the maxilla lateral to the lacrimal groove. Passing lateralwards, backwards, and upwards, at first between the Rectus inferior and the floor of the orbit, and then between the bulb of the eye and the Rectus lateralis, it is inserted into the lateral part of the sclera between the Rectus superior and Rectus lateralis, near to, but somewhat behind, the insertion of the Obliquus superior.

Nerves.—The Levator palpebræ superioris, the Obliquus inferior, and the Recti superior, inferior, et medialis are supplied by the oculomotor nerve; the Obliquus superior, by the trochlear nerve; the Rectus lateralis, by the abducent nerve.

Actions.—The Levator palpebræ raises the upper eyelid, and is the direct antagonist of the Orbicularis oculi. The four Recti are attached to the bulb of the eye in such a manner that, acting singly, they will turn its corneal surface either upwards, downwards, medialwards, or lateralwards, as expressed by their names. The movement produced by the Rectus superior and by the Rectus inferior is not quite a simple one, for inasmuch as each passes obliquely lateralwards and forwards to the bulb of the eye, the elevation or depression of the cornea is accompanied by a certain deviation medialwards, with a slight amount of rotation. These latter movements are corrected by the Obliqui, the Obliquus inferior correcting the medial deviation caused by the Rectus superior, and the Obliquus superior that caused by the Rectus inferior. The contraction of the Rectus lateralis or Rectus medialis, on the other hand, produces a purely horizontal movement. If any two neighbouring Recti of one eye act together they carry the globe of the eye in the diagonal of these directions, viz. upwards and medialwards, upwards and lateralwards, downwards and medialwards, or downwards and lateralwards. Sometimes the corresponding Recti of the two eyes act in unison, and at other times the opposite Recti act together. Thus, in turning the eyes to the right, the Rectus lateralis of the right eye acts in unison with the Rectus medialis of the left eye; but if both eyes are directed to an object in the middle line at a short distance, the two Recti medialis act in unison. The movement of circumduction, as in looking round a room, is performed by the successive actions of the four Recti. The Obliqui rotate the bulb of the eye on its anteroposterior axis, the superior directing the cornea downwards and lateralwards, and the inferior directing it upwards and lateralwards; these movements are required for the correct viewing of an object when the head is moved laterally, as from shoulder to shoulder, in order that the picture may fall in all respects on the same part of the retina of either eye.

A layer of non-striped muscle, the *Orbitalis muscle*, bridges the inferior orbital fissure.

The **fascia bulbi** (capsule of Tenon) (figs. 970, 971) is a thin membrane which envelops the bulb of the eye from the optic nerve to the corneoscleral junction, separating it from the orbital fat and forming a socket in which it plays. Its inner surface is smooth, and is separated from the outer surface of the sclera by the *episcleral space*; this space is traversed by delicate bands of connective tissue which extend between the fascia and the sclera. The fascia is perforated behind by the ciliary vessels and nerves, and fuses with the sheath of the optic nerve and with the sclera around the entrance of the optic nerve. In front it blends with the sclera just behind the corneoscleral junction. It is perforated anteriorly by the tendons of the ocular muscles, and is reflected backwards on each as a tubular sheath. The sheath of the Obliquus superior is carried as far as the fibrous pulley of that muscle; that on the Obliquus inferior reaches as far as the floor of the orbit, to which it gives off a slip. The sheaths on the Recti are gradually lost in the perimysium, but they give off important expansions. The expansion from the Rectus superior blends with the tendon of the Levator palpebræ superioris; that of the Rectus inferior is attached to the inferior tarsus. The expansions from the sheaths of the Recti medialis et lateralis are strong and triangular in shape, and are attached to the lacrimal and zygomatic bones respectively. As they probably check the actions of these two Recti they have been named the *medial* and *lateral check ligaments*. Lockwood * described a thickening of the lower part of the fascia bulbi, which he named the *suspensory ligament of the eye*; it is slung like a hammock below the eyeball, being expanded in the centre, and narrow at its extremities; it is formed by the union of the margins of the sheath of the Rectus inferior with the medial and lateral check ligaments.

* C. B. Lockwood, *Journal of Anatomy and Physiology*, vol. xx.

FIG. 970.—A scheme of the fascia of the orbit (the muscle-sheaths and the fascia bulbi) in sagittal section. (*From Whitnall's "Anatomy of the human orbit"*; Oxford Medical Publications.)

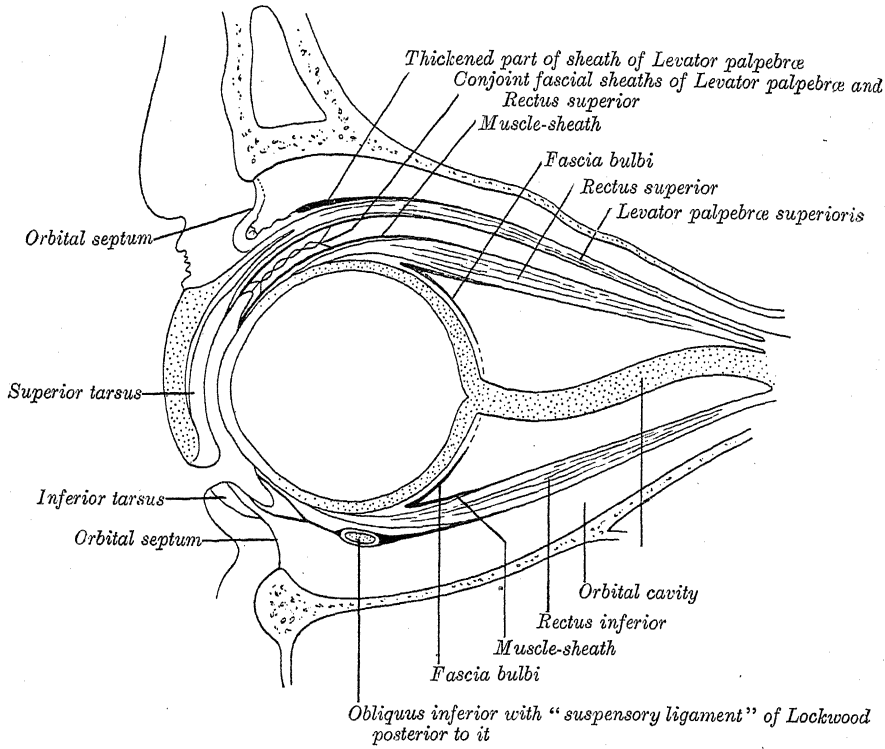
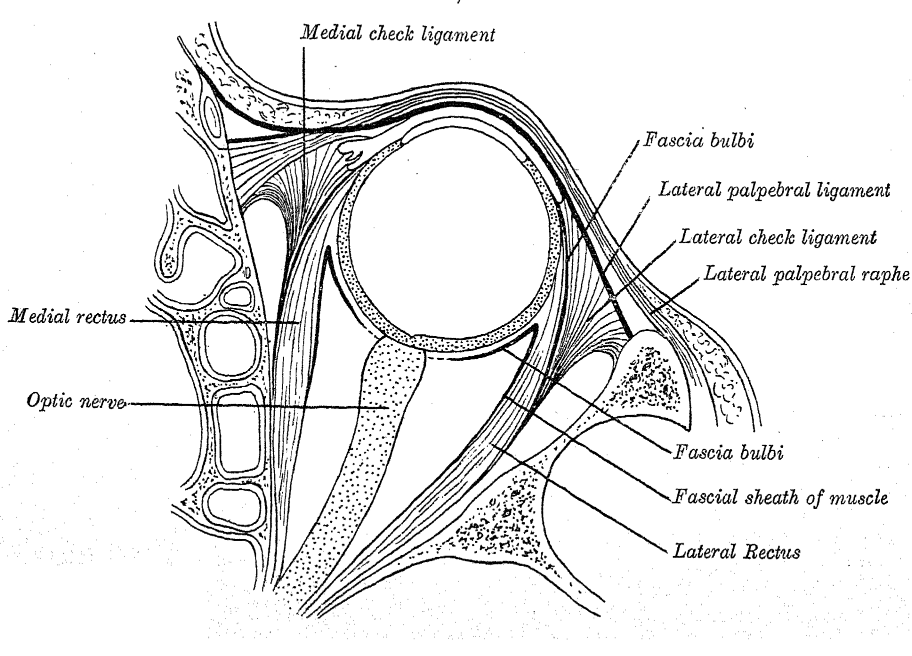


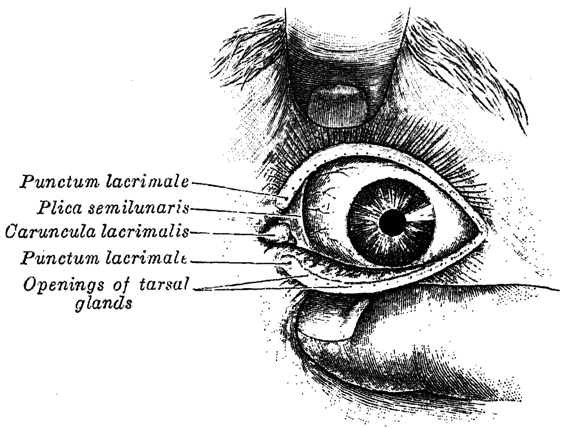
FIG. 971.—A schematic view of a horizontal section through the right orbit to illustrate the fascia of the orbit. (*From Whitnall's "Anatomy of the human orbit"*; Oxford Medical Publications.)



The **orbital fascia** forms the periosteum of the orbit, but is loosely connected to the bones. Behind, it is united with the dura mater and with the sheath of the optic nerve. In front, it is connected with the periosteum at the margin of the orbit, and sends off a stratum which assists in forming the orbital septum. From it two processes are given off: one holds the pulley of the Obliquus superior in position, the other, named the *lacrimal fascia*, forms the roof and lateral wall of the fossa in which the lacrimal sac is lodged (p. 1020).

Applied Anatomy.—The positions and exact areas of insertion of the tendons of the Recti medialis and lateralis into the bulb of the eye should be carefully examined from the front, as the surgeon is often required to divide one or other of the muscles for the cure of strabismus. In convergent strabismus, which is the more common form of the disease, the eye is turned medialwards, which may require the division of the Rectus medialis. In the divergent form, which is more rare, the eye is turned lateralwards, the Rectus lateralis being especially implicated. If the deformity produced in either case be marked, it may be remedied by division of one or the other muscle. The operation is thus performed: the lids are to be well separated; the eyeball is rotated lateralwards or medialwards, and the conjunctiva raised by a pair of forceps, and incised immediately beneath the lower border of the tendon of the muscle to be divided, a little behind its insertion into the sclera; the submucous areolar tissue is then divided, and into the small aperture thus made, a blunt hook is passed upwards between the muscle and the bulb, and the tendon of the muscle divided by a pair of blunt-pointed scissors passed between the hook and the bulb.

Fig. 972.—The front of the left eye with the eyelids separated to show the plica semilunaris, caruncula lacrimalis and puncta lacrimalia.



The converse operation is that of *advancement*, in which either the Rectus medialis or Rectus lateralis (depending on the form of strabismus) is shortened. The muscle is exposed in a similar manner; its tendon is divided, and sutured to the globe of the eye in front of its previous site of attachment.

Removal of the eyeball is effected by dividing the conjunctiva all round with scissors at its attachment to the cornea, after which each ocular muscle in turn is picked up on a blunt hook and divided close to the sclera. The optic nerve is then divided with curved scissors passed to the back of the orbit; it should be remembered that the perineural sheaths from the meninges are opened by this manœuvre.

Exophthalmos, or abnormal protrusion of the eyeball, is usually bilateral. It is almost always present in exophthalmic goitre or Graves' disease, in which it is due to abnormal stimulation of the cervical sympathetic nerves producing spasm of Müller's muscle, which passes between the eyeball and the eyelids. Less often it results from venous congestion of the orbital veins due to thrombosis of the cavernous sinuses. Unilateral exophthalmos is rare, and is caused by orbital cellulitis, periostitis, or new growth, or by traumatic arterial or arteriovenous aneurysm of the carotid artery behind the orbit. Intermittent exophthalmos, occurring only when the head is depressed, is very rare, and is due to the presence of varicose veins in the orbit.

In hydrocephalus the eyeball may be forced down so low in the orbit, through depression of the orbital plate of the frontal bone by the accumulation of fluid within the brain, that the patient, usually an infant, loses his sight because the pupil comes to lie below the lower eyelid even when the eye is open.

The **eyebrows** are two arched eminences of skin, which surmount the orbits, and support numerous short, thick hairs directed obliquely on the surface. Fibres of the Orbicularis oculi, Corrugator, and Frontalis muscles are inserted into the skin of the eyebrows.

The **eyelids** or **palpebrae** are two thin, movable folds, placed in front of the eye, and protecting it, by their closure, from injury. The upper eyelid is the larger and more movable, and is furnished with an elevator muscle, the Levator palpebræ superioris (p. 1010); the two eyelids unite with one another at their extremities to form the medial and lateral *palpebral commissures*.

When the eyelids are open, an elliptical space, the palpebral fissure (*rima palpebrarum*) is left between their margins ; the extremities of the fissure are called the angles or canthi.

The *lateral angle* or *canthus* is more acute than the medial, and lies in close contact with the bulb of the eye. The *medial angle* is prolonged for a short distance towards the nose, and is about 6 mm. away from the bulb of the eye; the two eyelids are here separated by a triangular space, the *lacus lacrimalis*, in which is situated a small reddish body, the *caruncula lacrimalis* (fig. 972). On the margin of each eyelid, at the basal angles of the lacus lacrimalis, is a small conical elevation, the *lacrimal papilla*, the apex of which is pierced by a minute orifice, the *punctum lacrimale*, the commencement of the lacrimal duct.

The *eyelashes* are attached to the free edges of the eyelids from the lateral palpebral commissure to the lacrimal papillæ. They are short, thick, curved hairs, arranged in double or triple rows: those of the upper eyelid, more numerous and longer than those of the lower, curve upwards; those of the lower eyelid curve downwards, so that the upper and lower eyelashes do not interlace in closing the lids. Near the attachments of the eyelashes are the openings of a number of glands, the *ciliary glands*, arranged in several rows close to the free margin of each lid; they are enlarged and modified sudoriferous glands.

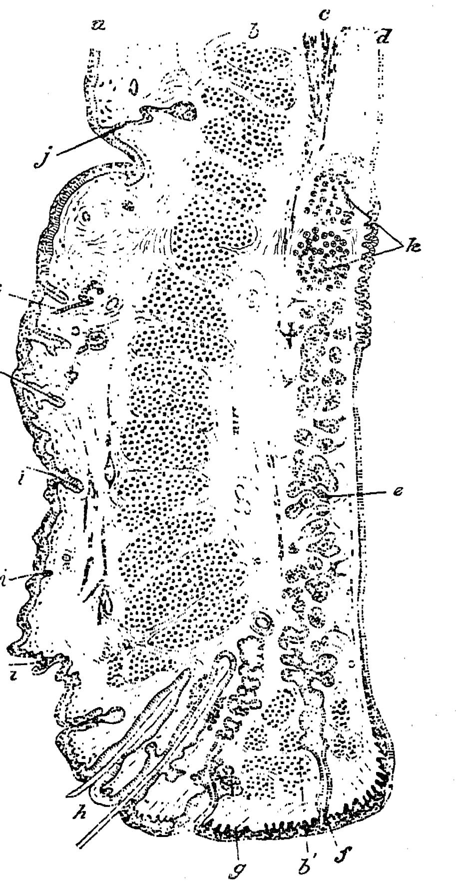
Structure of the eyelids.—From without inwards, each eyelid consists of: skin, subcutaneous areolar tissue, fibres of the Orbicularis oculi, tarsus, orbital septum, tarsal glands and conjunctiva. The upper eyelid has, in addition, the aponeurosis of the Levator palpebræ superioris (fig. 973).

The *skin* is extremely thin, and continuous at the margins of the eyelids with the conjunctiva.

The *subcutaneous areolar tissue* is very lax and delicate, and seldom contains any fat.

The *palpebral fibres of the Orbicularis oculi* are thin, pale in colour, and parallel to the palpebral fissure.

FIG. 973.—A sagittal section through the upper eyelid. (After Waldeyer.)

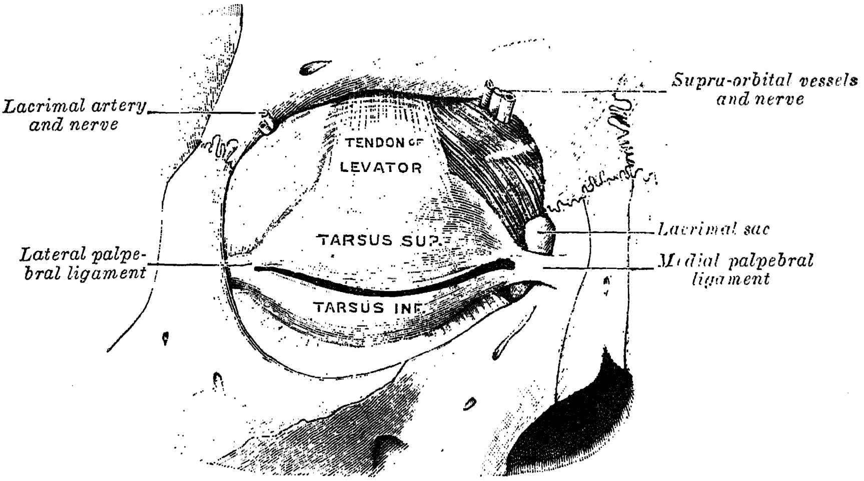


a. Skin. *b.* Orbicularis oculi. *b'.* Marginal fasciculus of the Orbicularis oculi (ciliary bundle). *c.* Levator palpebræ superioris. *d.* Conjunctiva. *e.* Tarsal glands. *f.* Opening of a tarsal gland. *g.* Sebaceous gland. *h.* Eyelashes. *i.* Small hairs of the skin. *j.* Sweat-gland. *k.* Posterior tarsal glands.

The *tarsi* (fig. 974) are two thin elongated plates of dense connective tissue, about 2·5 cm. long; one is placed in each eyelid, and contributes to its form and support. The *superior tarsus*, the larger, is of a semilunar form about 10 mm. in height at the centre, and gradually narrowing towards its extremities. The lowest fibres of the superficial lamella of the aponeurosis of the Levator palpebræ superioris are attached to the anterior surface, and the deep lamella of the same aponeurosis is inserted into the upper margin of the superior tarsus (p. 1010). The *inferior tarsus*, the smaller, is a narrow plate, the vertical diameter of which is about 5 mm. The free or ciliary margins of the tarsi are thick and straight. The attached or orbital margins are connected to the circumference of the orbit by the orbital septum. The lateral ends of the tarsi are attached

by a band, named the *lateral palpebral ligament*, to a tubercle on the zygomatic bone, just within the orbital margin; this ligament is separated from the more superficially placed lateral palpebral raphe (p. 439) by a few lobules of the lacrimal gland. The medial ends of the tarsi are attached by a strong tendinous band, named the *medial palpebral ligament* (tendo oculi) to the upper part of the anterior lacrimal crest, and to the adjoining part of the frontal process of the

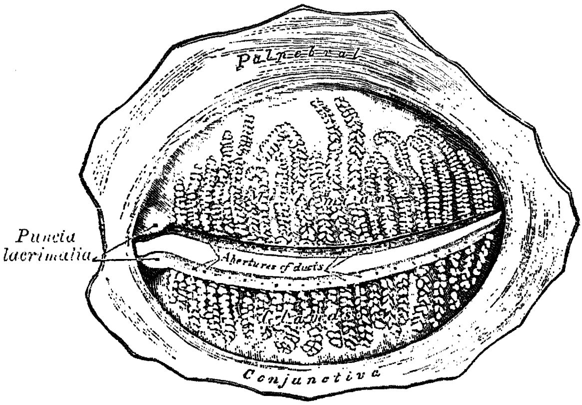
FIG. 974.—The tarsi and their ligaments. Anterior aspect. (Testut.)



maxilla in front of this crest; the lower edge of this ligament is separated from the lacrimal sac by some fibres of the Orbicularis oculi.

The *orbital septum* is a membranous sheet, attached to the edge of the orbit, where it is continuous with the periosteum. In the upper eyelid it blends with the superficial lamella of the aponeurosis of the Levator palpebræ superioris, and in the lower eyelid with the anterior surface of the inferior tarsus. It is perforated by the vessels and nerves which pass from the orbital cavity to the face and scalp.

FIG. 975.—The tarsal glands of the eyelids. Posterior aspect.



The *tarsal glands* (Meibomian glands) (fig. 975) are situated between the tarsi and conjunctiva, and may be distinctly seen through the latter on everting the eyelids, presenting an appearance like parallel strings of pearls. There are about thirty in the upper eyelid, and somewhat fewer in the lower. They are imbedded in grooves in the inner surfaces of the tarsi and correspond in length with the breadth of these plates; they are, consequently, longer in the upper than in the lower eyelid. Their ducts open on the free margins of the lids by minute foramina.

Structure.—The tarsal glands are modified sebaceous glands, each consisting of a straight tube or follicle, with numerous small lateral diverticula. The tubes are supported by a basement-membrane, and are lined at their mouths by stratified epithelium; the deeper parts of the tubes and the lateral offshoots are lined by a layer of polyhedral cells.

The **conjunctiva** is the mucous membrane of the eye. It lines the inner surfaces of the eyelids or palpebræ, and is reflected over the fore part of the sclera and the cornea.

The *palpebral portion* is thick, opaque, highly vascular, and has numerous subepithelial connective tissue papillæ, its deeper part containing a considerable amount of lymphoid tissue. At the margins of the lids it is continuous with the lining membranes of the ducts of the tarsal glands, and, through the lacrimal ducts, with the lining membrane of the lacrimal sac and nasolacrimal duct. Beneath the lateral part of the upper eyelid the ducts of the lacrimal gland open on its free surface. The line of reflection of the conjunctiva from the eyelids on to the bulb of the eye is named the *conjunctival fornix*, and its different parts are known as the superior, inferior, medial and lateral fornices; on account of the greater size of the upper eyelid the superior fornix appears to be situated further back than the inferior. Upon the *sclera* the conjunctiva is loosely connected to the bulb of the eye; it is thin, transparent, destitute of papillæ, and only slightly vascular. Upon the *cornea*, the conjunctiva consists only of epithelium, constituting the epithelium of the cornea, already described (p. 996). The epithelium of the palpebral conjunctiva is columnar, that of the ocular conjunctiva and the cornea is stratified squamous. *Lymphatics* arise in a delicate zone around the cornea, and run to the ocular conjunctiva.

Glands, analogous to lymphoid follicles, and called by Henle *trachoma glands*, are found in the conjunctiva, and, according to Strohmeyer, are chiefly situated near the medial palpebral commissure. They were first described by Brush, in his description of Peyer's patches of the small intestine, as 'identical structures existing in the under eyelid of the ox.'

The *caruncula lacrimalis* (fig. 972) is a small, reddish, conical body situated in the lacus lacrimalis at the medial palpebral commissure. It consists of a small island of skin containing sebaceous and sudoriferous glands, and is the source of the whitish secretion which collects in this region. A few slender hairs are attached to its surface. Lateral to the caruncula is a semilunar fold of conjunctiva, the *plica semilunaris*, the concavity of which is directed towards the cornea. Müller found unstriped muscular fibres in this fold; in some of the domesticated animals it contains a thin plate of cartilage.

The nerves of the conjunctiva are numerous; many of them end in terminal bulbs, first described by Krause (p. 1048).

The lymphatic vessels of the eyelids and the conjunctiva are described on p. 754.

The Lacrimal Apparatus (figs. 976 to 979)

The lacrimal apparatus consists of (a) the lacrimal gland which secretes the tears, and its excretory ducts which convey the fluid to the surface of the eye; (b) the lacrimal ducts, the lacrimal sac, and the nasolacrimal duct, by which the fluid is conveyed into the cavity of the nose.

The **lacrimal gland** (fig. 976) is lodged in a fossa, on the medial side of the zygomatic process of the frontal bone. It is about the size and shape of an almond, and consists of two portions, described as the superior and inferior lacrimal glands; the two parts are, however, joined to one another around the lateral edge of the aponeurosis of the Levator palpebræ superioris. The *superior lacrimal gland* is connected to the periosteum of the orbit by a few fibrous bands; the *inferior lacrimal gland* lies beneath the aponeurosis of the Levator palpebræ superioris, and projects into the posterior part of the upper eyelid, where it lies upon and is adherent to the conjunctiva. The ducts of the glands, from six to twelve in number, run obliquely beneath the conjunctiva for a short distance, and open along the lateral part of the superior conjunctival fornix.

In and near the conjunctival fornices, but more plentiful in the upper than in the lower lid, are many small *accessory lacrimal glands*; the presence of these may explain why the conjunctiva does not dry up after extirpation of the lacrimal gland proper.

Structure of the lacrimal gland (fig. 977).—In structure the lacrimal resembles the salivary glands (p. 1100), but there are no crescents of Guianuzzi. It is a compound racemose gland, the alveoli of which are lined with columnar cells resting on a basement-membrane. The cells contain oval nuclei, and in the resting condition are crowded with small clear vacuoles, which disappear when the gland secretes actively; protoplasmic granules are also present. The excretory ducts are lined with columnar epithelial cells, but these cells do not show the rod-like structures of the corresponding cells in the salivary glands.

FIG. 976.—The left lacrimal apparatus. Exposed from the front.

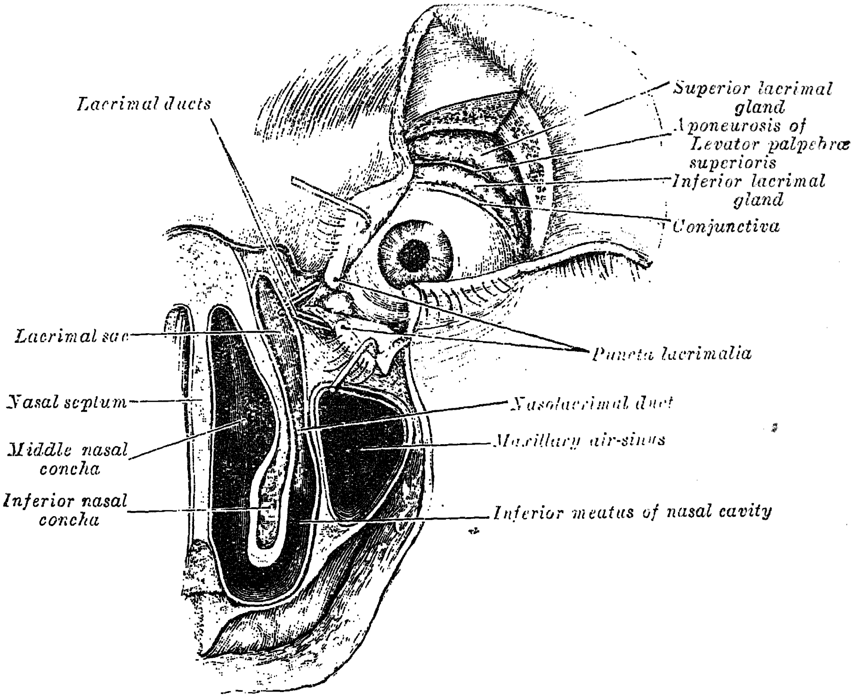
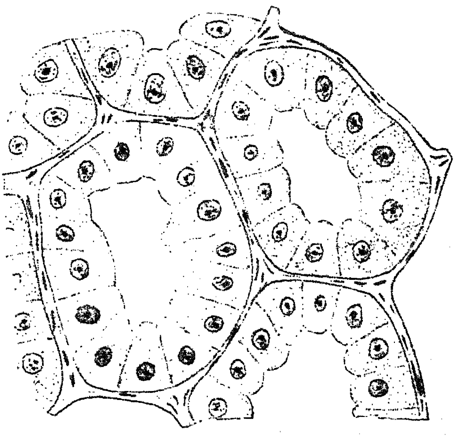


FIG. 977.—A transverse section through a portion of the lacrimal gland of a cat. × 250.

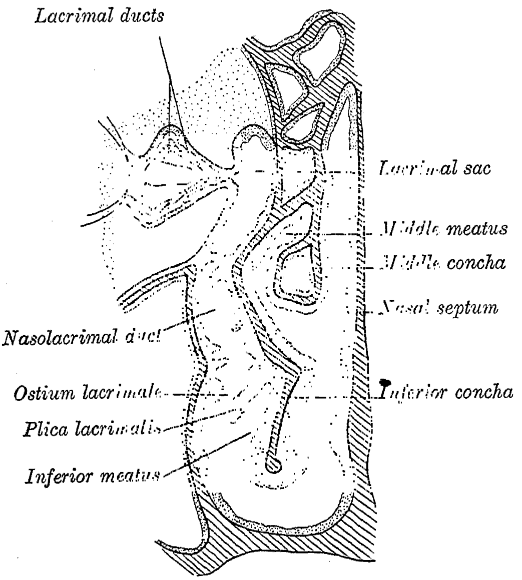


The **lacrimal ducts or canals**, one in each eyelid, are about 10 mm. long; they commence at minute orifices, the *puncta lacrimalia* (figs. 972, 976, 978), situated on the summits of the *papillæ lacrimales*, which are seen on the margins of the lids at the basal angles of the lacus lacrimalis. The *superior duct*, smaller and shorter than the inferior, at first ascends, and then bends at an acute angle, and passes medialwards and downwards to the lacrimal sac. The *inferior duct* at first descends, and then runs almost horizontally to the lacrimal sac. At the angles they are dilated into *ampullæ*. The mucous lining of the ducts is covered with stratified squamous epithelium, placed on a basement-membrane, and outside the latter is a layer of striped muscular fibres, continuous with the lacrimal part of the Orbicularis

oculi; at the base of each lacrimal papilla the muscular fibres are circularly arranged and form a kind of sphincter.

The **lacrimal sac** (fig. 978) is the upper end of the nasolacrimal duct, and is lodged in a fossa formed by the lacrimal bone, the frontal process of the maxilla and the lacrimal fascia. It measures about 12 mm. in length; its upper, closed end is flattened from side to side, but its lower part is rounded, and is continued into the nasolacrimal duct; in its lateral wall are the openings of the lacrimal ducts.

FIG. 978.—Sketch from a frontal section through the right nasal cavity, viewed from the front, to show the relation of the lacrimal passages to the maxillary and ethmoidal sinuses and the inferior nasal concha. The mucous membrane is coloured. (After Gerard, 1907; *From Whitnall's "Anatomy of the human orbit"*; Oxford Medical Publications.)



Relations.—A fascia, continuous with the periosteum of the orbit, and named the *lacrimal fascia*, passes from the anterior to the posterior lacrimal crest, and forms the roof and lateral wall of the fossa in which the lacrimal sac is lodged; between the fascia and the lacrimal sac there is a minute plexus of veins. The lacrimal fascia separates the sac from the medial palpebral ligament (tendo oculi) in front, and from the lacrimal part of the Orbicularis oculi (Tensor tarsi) behind. The lower half of the fossa which lodges the lacrimal sac is related medially with the anterior part of the middle meatus of the nasal cavity; the upper half with the anterior ethmoidal air-sinuses.*

Structure.—The lacrimal sac consists of a fibro-elastic coat, lined internally by mucous membrane; the latter is continuous, through the lacrimal ducts, with the conjunctiva, and through the nasolacrimal duct with the mucous membrane of the nasal cavity.

The tears pass from the superolateral to the inferomedial angle of the conjunctival sac. They are directed by: (*a*) the medialward pull of the Orbicularis oculi; (*b*) the contractions of the muscle around the lacrimal ducts; and (*c*) the compression of the lacrimal sac by the lacrimal part of the Orbicularis oculi.

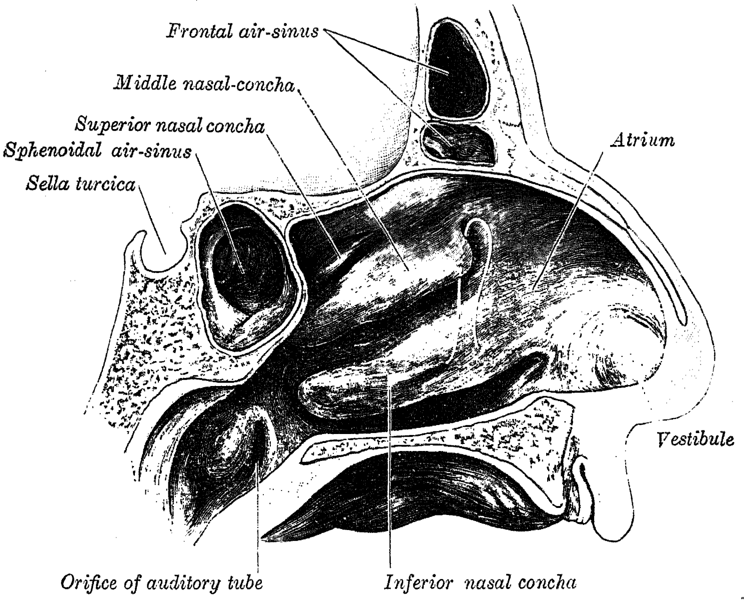
The **nasolacrimal duct** (nasal duct) (figs. 978, 979) is a membranous canal, about 18 mm. long, which extends from the lower part of the lacrimal sac to the anterior part of the inferior meatus of the nose, where it ends in a somewhat expanded orifice, provided with an imperfect valve, the *plica lacrimalis* (*Hasneri*), formed by a fold of the mucous membrane. The duct is contained in an osseous canal, formed by the maxilla, the lacrimal bone, and the inferior nasal concha; it is narrower in the middle than at either end, and is directed downwards, backwards, and a little lateralwards. The mucous lining of the lacrimal sac and nasolacrimal duct is covered with columnar epithelium which in places is ciliated.

Applied Anatomy.—The eyelids are composed of various tissues, and consequently are liable to a variety of diseases. The skin covering them is thin and delicate, and is supported on a quantity of loose areolar subcutaneous tissue, devoid of fat. In consequence of this it is very freely movable, and is liable to be drawn down by the contraction

* S. E. Whitnall (*Ophthalmic Review*, Nov. 1911) examined 100 skulls and found that in 14 the anterior ethmoidal air-sinuses came into relation only with the posterior wall of the fossa; in 32 they reached as far forward as the suture between the lacrimal bone and the maxilla; while in 54 one large irregular air-sinus extended forward as far as the anterior lacrimal crest.

of neighbouring cicatrices, and thus produce an eversion of the lid, known as *ectropion.* Inversion of the lids (*entropion*) from spasm of the Orbicularis oculi or from chronic inflammation of the palpebral conjunctiva may also occur. The loose cellular tissue beneath the skin is liable to become extensively infiltrated either with blood or inflammatory products, producing very great swelling. Even from very slight injuries to this tissue, the extravasation of blood may be so great as to produce considerable swelling of the eyelids and complete closure of the eye, and the same is the case when inflammatory products are poured out. The follicles of the eyelashes, or the sebaceous glands associated with these follicles, may be the seat of inflammation, constituting the ordinary 'stye.' Irregular or disorderly growth of the eyelashes not infrequently occurs, some of them being turned towards the eyeball and producing inflammation and ulceration of the cornea, and possibly eventually complete destruction of the eye. The Orbicularis oculi may be the seat of spasm, either in the form of slight quivering of the lids; or repeated twitchings, most commonly due to errors of refraction in children; or more continuous spasms, due to some irritation of the trigeminal or of the facial nerve. The Orbicularis

Fig. 979.—A sagittal section through the anterior part of the head of an adult female. Left half viewed from within to show the left lateral nasal wall. The relative positions of the fossa for the lacrimal sac and the naso-lacrimal duct are indicated by the white line. × about $\frac{2}{3}$. (*From Whitnall's "Anatomy of the human orbit"*; Oxford Medical Publications.)



oculi may be paralysed with the other facial muscles. Under these circumstances the patient is unable to close the lids, and, if he attempts to do so, rolls the eyeball upwards under the upper eyelid. The tears overflow from displacement of the lower eyelid, and the conjunctiva and cornea, being constantly exposed and the patient being unable to wink, become irritated from dust and foreign bodies. Ptosis, or drooping of the upper eyelid, may be congenital, or may be due to paralysis of the Levator palpebræ superioris, in which case there will probably be other symptoms of implication of the oculomotor nerve. The eyelids may be the seat of bruises, wounds, or burns. Following burns, adhesion of the margins of the lids to each other, or adhesion of the lids to the bulb of the eye may take place. They are sometimes the seat of emphysema, after fracture of some of the thin bones forming the medial wall of the orbit. If shortly after such an injury the patient blows his nose, air is forced from the nostril through the lacerated structures into the connective tissue of the eyelids, which suddenly swell up and present the peculiar crackling characteristic of this affection.

Foreign bodies frequently get into the conjunctival sac and cause great pain, especially if they come in contact with the corneal surface, during the movements of the eyelids. The conjunctiva is often involved in severe injuries of the eyeball, but is seldom ruptured alone; the most common form of injury to the conjunctiva alone is from a burn, either from fire, strong acids, or lime. In these cases union is liable to take place between the eyelid and the eyeball. The conjunctiva is often the seat of inflammation arising from

many different causes, and the arrangement of the conjunctival vessels should be remembered as affording a means of diagnosis between this condition and injection of the sclera, which is present in inflammation of the deeper structures of the bulb of the eye. The inflamed conjunctiva is bright red; the vessels are large and tortuous, and greatest at the circumference, shading off towards the corneal margin; they anastomose freely and form a dense network, and they can be emptied or displaced by gentle pressure. Inflammation of the underlying sclera, ciliary body, or iris, is a far more serious condition; the injection is in the deeper vessels of the eye, and as seen through the sclera presents a diffuse and dull purplish or violet zone of circumcorneal discoloration.

The lacrimal ducts may become occluded as a result of burns or injury; overflow of the tears may also result from deviation of the puncta, or from chronic inflammation of the lacrimal sac. This latter condition is set up by some obstruction to the nasolacrimal duct, frequently associated with some infection from the nasal cavity. In consequence of this the tears and mucus accumulate in the lacrimal sac and distend it. Suppuration in the lacrimal sac is sometimes met with; this may be the sequel of a chronic inflammation. It may lead to lacrimal fistula from an abscess forming in the sac, which bursts or is opened on the surface; the condition is often seen in badly nourished, tuberculous children.

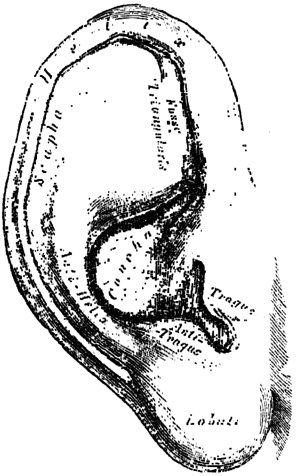
The Organ of Hearing

The ear or organ of hearing is divisible into three parts: the external ear, the middle ear or tympanic cavity, and the internal ear or labyrinth.

The External Ear

The **external ear** consists of the expanded portion named the *auricula* or *pinna*, and the *external acoustic meatus*. The former projects from the side of the head and serves to collect the air-vibrations by which sound is produced; the latter leads inwards from the bottom of the auricula and conducts the vibrations to the tympanic cavity.

Fig. 980.—The right auricula. Lateral surface.



The **auricula or pinna** (fig. 980) is of an oval form, with its larger end directed upwards. Its lateral surface is irregularly concave, looks slightly forwards, and presents numerous eminences and depressions. The prominent rim of the auricula is called the *helix*; where the helix turns downwards posteriorly, a small tubercle, the *auricular tubercle of Darwin*, is frequently seen; this tubercle is very evident about the sixth month of fœtal life, when the whole auricula has a close resemblance to that of some of the adult monkeys. Another curved prominence, parallel with and in front of the helix, is called the *antihelix*; this divides above into two crura, between which is a triangular depression, the *fossa triangularis*. The narrow curved depression between the helix and the antihelix is called the *scapha*; the antihelix partly encircles a deep, capacious cavity, the *concha*, which is incompletely divided into two parts by the *crus* or anterior end of the helix; the upper part is termed the *cymba conchæ*, the lower part the *cavum conchæ*. In front of the concha, and projecting backwards over the meatus, is a small eminence, the *tragus*. Opposite the tragus, and separated from it by the *intertragic notch*, is a small tubercle, the *antitragus*. Below the antitragus is the *lobule*, composed of fibrous and adipose tissues, and devoid of the firmness and elasticity of the rest of the auricula.

The cranial surface of the auricula presents elevations which correspond to the depressions on its lateral surface, and after which they are named, e.g. eminentia conchæ, eminentia triangularis, &c.

Structure.—The auricula is composed of a thin plate of yellow fibrocartilage, covered with skin, and connected to the surrounding parts by ligaments and muscles; it is continuous with the cartilaginous portion of the external acoustic

meatus, and the latter is joined to the circumference of the porus acusticus externus by fibrous tissue.

The *skin of the auricula* is thin, closely adherent to the cartilage, and covered with fine hairs which are furnished with sebaceous glands; these glands are most numerous in the concha and scaphoid fossa. On the tragus and antitragus, and in the intertragic notch the hairs are strong and numerous. The skin of the auricula is continuous with that lining the external acoustic meatus.

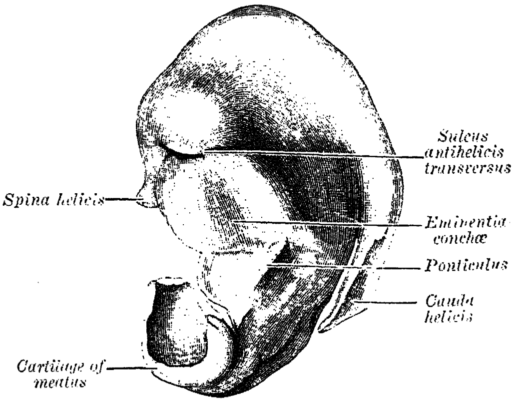


Fig. 981.—The cranial surface of the cartilage of the right auricula.

The *cartilage of the auricula* (figs. 981, 982) consists of a single piece; upon its surface are found the eminences and depressions above described. It is absent from the lobule; it is deficient, also, between the tragus and beginning of the helix, the gap being filled up by dense fibrous tissue. At the front part of the auricula, where the helix bends upwards, is a small projection of the cartilage, called the *spina helicis*, while in the lower part of the helix the cartilage is prolonged downwards as a tail-like process, the *cauda helicis*; the latter is separated from the antihelix by a fissure, the *fissura antitragohelicina*. The cranial surface of the cartilage exhibits a transverse furrow, the *sulcus antihelicis transversus*, which corresponds with the inferior crus of the antihelix and separates the eminentia conchæ from the eminentia triangularis. The eminentia conchæ is crossed by a vertical ridge (*ponticulus*) which gives attachment to the Auricularis posterior muscle. In the cartilage of the auricula are two fissures, one behind the crus helicis and another in the tragus.

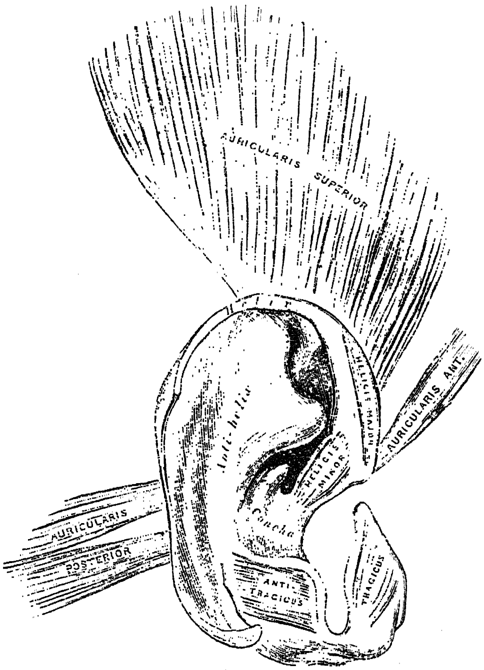


Fig. 982.—The muscles of the right auricula.

The *ligaments of the auricula* consist of two sets: (1) extrinsic, connecting it to the temporal bone; (2) intrinsic, connecting various parts of its cartilage together.

The *extrinsic ligaments* are two in number, anterior and posterior. The *anterior ligament* extends from the tragus and spina helicis to the root of the zygomatic process of the temporal bone. The *posterior ligament* passes from the posterior surface of the concha to the outer surface of the mastoid process.

The chief *intrinsic ligaments* are: (*a*) a strong fibrous band, stretching from the tragus to the helix, completing the meatus in front, and partly encircling the boundary of the concha; and (*b*) a band between the antihelix and the cauda helicis. Other less important bands are found on the cranial surface of the pinna.

The *muscles of the auricula* (fig. 982) consist of two sets: (1) the extrinsic, which connect it with the skull and scalp and move the auricula as a whole; and (2) the intrinsic, which extend from one part of the auricula to another.

The **extrinsic muscles** are the Auriculares anterior, superior, et posterior.

The *Auricularis anterior*, the smallest of the three, is thin, fan-shaped, and its fibres are pale and indistinct. It arises from the lateral edge of the galea aponeurotica, and its fibres converge to be inserted into the spina helicis.

The *Auricularis superior*, the largest of the three, is thin and fan-shaped. Its fibres arise from the galea aponeurotica, and converge to be inserted by a thin, flattened tendon into the upper part of the cranial surface of the auricula.

The *Auricularis posterior* consists of two or three fleshy fasciculi, which arise by short aponeurotic fibres from the mastoid portion of the temporal bone, and are inserted into the ponticulus on the eminentia conchæ.

Nerve-supply.—The Auriculares anterior et superior are supplied by the temporal branches, and the Auricularis posterior by the posterior auricular branch, of the facial nerve.

Actions.—In man, these muscles possess very little action: the Auricularis anterior draws the auricula forwards and upwards; the Auricularis superior slightly raises it; and the Auricularis posterior draws it backwards.

The **intrinsic muscles** are the:

Helicis major.	Antitragicus.
Helicis minor.	Transversus auriculæ.
Tragicus.	Obliquus auriculæ.

The *Helicis major* is a narrow vertical band situated upon the anterior margin of the helix. It arises from the spina helicis, and is inserted into the anterior border of the helix, where the latter is about to curve backwards.

The *Helicis minor* is an oblique fasciculus, covering the crus helicis.

The *Tragicus* is a short, flattened vertical band on the lateral surface of the tragus.

The *Antitragicus* arises from the outer part of the antitragus, and is inserted into the cauda helicis and antihelix.

The *Transversus auriculæ* is placed on the cranial surface of the pinna. It consists of scattered fibres, partly tendinous and partly muscular, extending from the eminentia conchæ to the eminentia scaphæ.

The *Obliquus auriculæ*, also on the cranial surface, consists of a few fibres extending from the upper and posterior parts of the eminentia conchæ to the eminentia triangularis.

Nerve-supply.—The intrinsic muscles on the lateral surface are supplied by the temporal branches of the facial nerve, the intrinsic muscles on the cranial surface by the posterior auricular branch of the same nerve.

The *arteries of the auricula* are: (*a*) the posterior auricular branch of the external carotid artery, which supplies three or four branches to the cranial surface; twigs from these reach the lateral surface, some by passing through the fissures of the auricular cartilage, and others by turning round the margin of the helix; (*b*) the anterior auricular branches of the superficial temporal artery, which are distributed to the lateral surface; and (*c*) a branch from the occipital artery.

The *veins* accompany the corresponding arteries.

The *sensory nerves* are: the great auricular and lesser occipital nerves, from the cervical plexus; the auriculotemporal branch of the mandibular nerve; and the auricular branch of the vagus nerve.

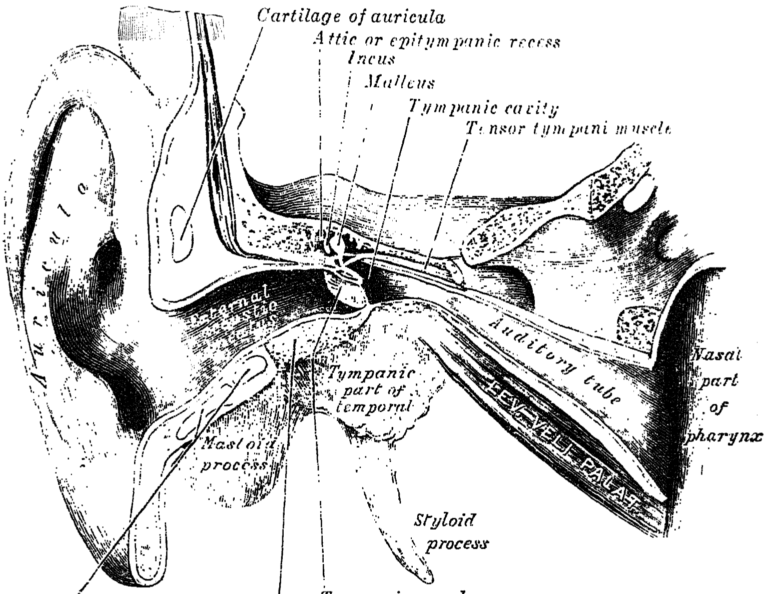
The **external acoustic meatus** extends from the bottom of the concha to the tympanic membrane (figs. 983, 984). It is about 4 cm. long if measured from the tragus; from the bottom of the concha its length is about 2·5 cm. It forms an S-shaped curve, and is directed at first inwards, forwards, and slightly upwards (*pars externa*); it then passes inwards, backwards, and upwards, (*pars media*), and lastly is carried inwards, forwards, and slightly downwards (*pars interna*). It is an oval cylindrical canal, the greatest diameter of the oval being directed downwards and backwards at the external orifice, but nearly horizontally at the inner end. It presents two constrictions, one near the inner end of the cartilaginous portion, and another, named the *isthmus*, in the osseous portion, about 2 cm. from the bottom of the concha. The tympanic membrane, which closes the inner end of the meatus, is obliquely directed; in consequence of this obliquity the floor and anterior wall of the meatus are longer than the roof and posterior wall.

The external acoustic meatus is formed partly by cartilage and membrane, and partly by bone, and is lined by skin.

The *cartilaginous portion* is about 8 mm. long; it is continuous with the cartilage of the auricula, and is fixed to the circumference of the porus acusticus externus of the temporal bone. The cartilage is deficient at the upper and posterior parts of the meatus, its place being supplied by fibrous membrane; two or three deep fissures are present in the anterior part of the cartilage.

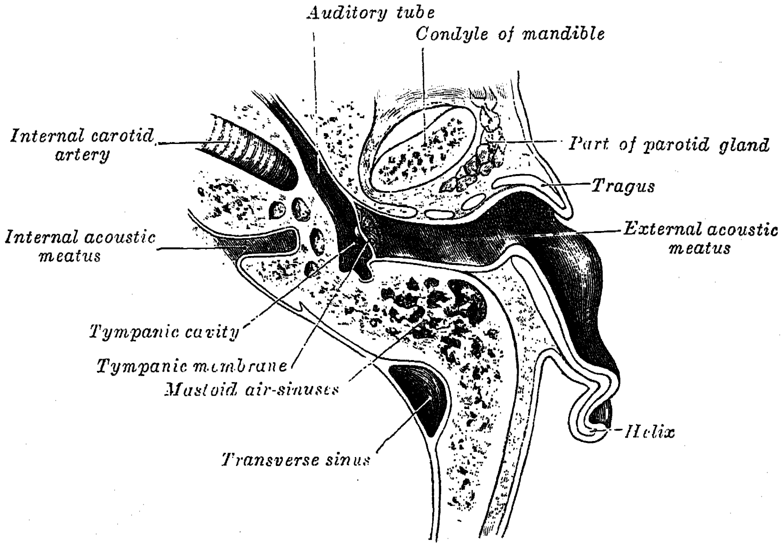
The *osseous portion* is about 16 mm. long, and is narrower than the cartilaginous portion. It is directed inwards, forwards, and slightly downwards,

Fig. 983.—The external and middle portions of the right ear, from the front.



forming in its course a slight curve the convexity of which is upwards and backwards. Its inner end is smaller than the outer, and sloped, the anterior wall projecting beyond the posterior for about 4 mm.; this end is marked,

Fig. 984.—A horizontal section through the left ear. Upper half of the section.



except at its upper part, by a narrow groove, the *tympanic sulcus*, in which the circumference of the tympanic membrane is attached. Its outer end

(porus acusticus externus) is dilated and rough in the greater part of its circumference, for the attachment of the cartilaginous portion. The anterior and inferior parts of the osseous portion are formed by the tympanic part of the temporal bone, which, in the fœtus, exists as the tympanic ring (p. 213).

The skin which envelops the auricula is continued into the external acoustic meatus and covers the outer surface of the tympanic membrane. It is thin and closely adherent to the cartilaginous and osseous parts of the tube. After maceration, the thin pouch of epidermis, when withdrawn, preserves the form of the meatus. In the thick subcutaneous tissue of the cartilaginous part of the meatus are numerous *ceruminous glands* which secrete the ear-wax ; their structure resembles that of the sudoriferous glands (p. 1057).

Relations of the meatus.—In front of the meatus is the condyle of the mandible, which, however, is sometimes separated from the cartilaginous part by a small portion of the parotid gland. The movements of the mandible influence to some extent the lumen of the cartilaginous portion. Above the osseous part is the middle cranial fossa; behind it are the mastoid air-sinuses, separated from the meatus by a thin layer of bone.

The *arteries* supplying the meatus are branches from the posterior auricular, internal maxillary, and temporal arteries.

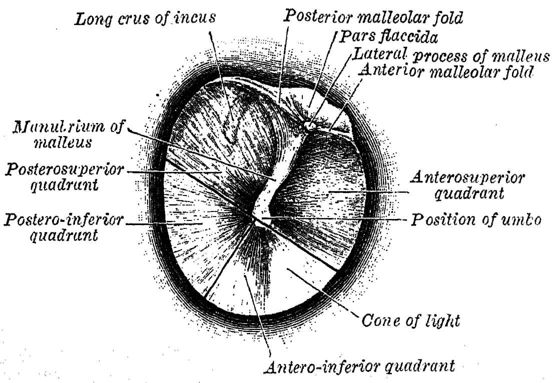
The *nerves* are chiefly derived from the auriculotemporal branch of the mandibular nerve and the auricular branch of the vagus nerve.

Applied Anatomy.—Malformations, such as imperfect development of the external parts, supernumerary auriculæ, or absence of the meatus, are occasionally met with. The skin of the auricula is thin and richly supplied with blood, but in spite of this it is often the seat of frost-bite, due to the fact that it is much exposed to cold, and lacks the usual underlying subcutaneous fat found in most other parts of the body. A collection of blood is sometimes found between the cartilage and perichondrium (*hæmatoma auris*), usually the result of traumatism, but not necessarily due to this cause; it is said to occur most frequently in the ears of the insane. Deposits of urate of soda are often met with in the auriculæ of gouty subjects.

The external acoustic meatus can be most satisfactorily examined by light reflected down a funnel-shaped speculum, when the greater part of the canal and tympanic membrane can be brought into view. In using this instrument, it is advisable that the auricula should be drawn upwards, backwards, and a little outwards, so as to render the meatus as straight as possible. The points to be noted are : the presence of wax or foreign bodies; the size of the meatus; and the condition of the tympanic membrane. Accumulation of wax is often a cause of deafness; it is best removed by syringing. Foreign bodies are not infrequently introduced into the ear by children, and, when situated in the first portion of the meatus, may be removed with tolerable facility by means of a minute hook or loop of fine wire, aided by reflected light; but when they have slipped beyond the narrow middle part of the meatus, their removal is in no wise easy, and attempts to effect it, in inexperienced hands, may be followed by destruction of the tympanic membrane and possibly the contents of the tympanic cavity.

At the point of junction of the osseous and cartilaginous portions an obtuse angle, which projects into the tube at its antero-inferior wall, is formed ; this produces a sort of constriction, and renders it a narrow portion of the meatus —an important point to be remembered in connexion with the presence of foreign bodies in the meatus. The shortness of the meatus in children should be borne in mind in introducing the aural speculum, so that it be not pushed in too far, at the risk of injuring the tympanic membrane; indeed, even in the adult the speculum should never be introduced beyond the constriction which marks the junction of the osseous and cartilaginous portions. Just in front of the membrane is a well-marked depression, situated on the floor of the meatus, and bounded by a somewhat prominent ridge ; in this foreign bodies may become lodged. By aid of the speculum, combined with traction of the auricle upwards and backwards, the greater part of the tympanic membrane is rendered visible (fig. 985). It is a pearly-grey membrane, slightly glistening in the adult, placed obliquely,

FIG. 985.—The right tympanic membrane, as seen through a speculum.



so as to form with the floor of the meatus a very acute angle (about fifty-five degrees), while with the roof it forms an obtuse angle. At birth it is more horizontal, situated in almost the same plane as the base of the skull. About midway between the anterior and posterior margins of the membrane, and extending from the centre obliquely upwards and forwards, is a reddish-yellow streak; this is the handle of the malleus, which is inserted into the membrane. At the upper part of this streak, close to the roof of the meatus, a little white, round prominence is plainly to be seen; this is the lateral or short process of the malleus, projecting against the membrane. The tympanic membrane does not present a plane surface; on the contrary, its centre is drawn inwards, on account of its connexion with the manubrium of the malleus.

The connexions of the nerves of the meatus explain the occurrence of constant coughing and sneezing, from implication of the vagus, when there exists any source of irritation in the meatus; and the vomiting which may follow syringing the ears of children, and the occasional heart failure similarly induced in elderly people. No doubt also the association of earache with toothache or with cancer of the tongue is due to implication of the mandibular branch of the trigeminal nerve, which supplies also the teeth and the tongue. The upper half of the tympanic membrane is much more vascular than the lower half; for this reason, and also to avoid the chorda tympani nerve and ossicles, incisions through the membrane should be made at the lower and posterior part.

The Middle Ear, or Tympanic Cavity

The **middle ear or tympanic cavity,** is an irregular, laterally compressed space within the temporal bone. It is filled with air, which is conveyed to it from the nasal part of the pharynx through the auditory tube. It contains a chain of movable bones which connect its lateral to its medial wall, and transmit the vibrations of the tympanic membrane across the cavity to the internal ear.

The tympanic cavity consists of two parts: the *tympanic cavity proper*, opposite the tympanic membrane, and the *attic* or *epitympanic recess*, above the level of the membrane; the latter contains the upper half of the malleus and the greater part of the incus. Including the attic, the vertical and antero-posterior diameters of the cavity are each about 15 mm. The transverse diameter measures about 6 mm. above and 4 mm. below; opposite the centre of the tympanic membrane it is only about 2 mm. The tympanic cavity is bounded laterally by the tympanic membrane; medially, by the lateral wall of the internal ear; it communicates, behind, with the tympanic antrum, and through it with the mastoid air-sinuses, and in front with the auditory tube (fig. 983).

The **tegmental wall or roof** of the tympanic cavity is formed by a thin plate of bone, the *tegmen tympani*, which separates the cranial and tympanic cavities, and forms the greater part of the anterior surface of the petrous portion of the temporal bone; it is prolonged backwards so as to roof the tympanic antrum, and forwards to cover the semicanal for the Tensor tympani.

The **jugular wall or floor** is narrow, and consists of a thin, convex plate of bone (*fundus tympani*) which separates the tympanic cavity from the superior bulb of the internal jugular vein; in places this bony wall may be deficient, and then the tympanic cavity is separated from the vein by mucous membrane and fibrous tissue only. In the floor of the tympanic cavity, near the labyrinthic wall, is a small aperture for the passage of the tympanic branch of the glossopharyngeal nerve.

The **membranous or lateral wall** of the tympanic cavity (fig. 986) is formed mainly by the tympanic membrane, but partly by the ring of bone in which this membrane is attached. There is a deficiency or notch in the upper part of the ring (*notch of Rivinus*), close to which are three small apertures, viz.: the iter chordæ posterius, the petrotympanic fissure, and the iter chordæ anterius.

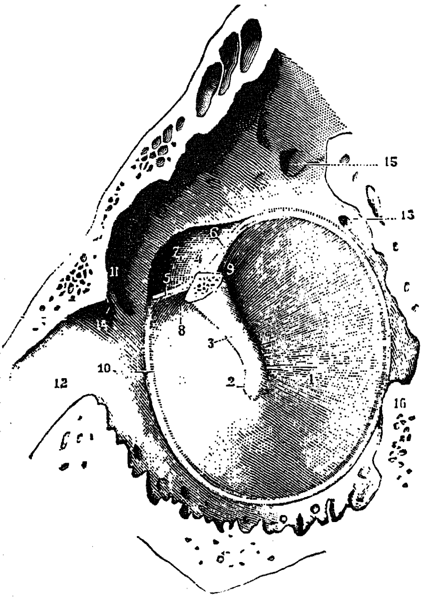
The *iter chordæ posterius* (apertura tympanica canaliculi chordæ) is situated in the angle of junction between the mastoid and membranous walls of the tympanic cavity immediately behind the tympanic membrane and on a level with the upper end of the manubrium mallei; it leads into a minute canal, which descends in front of the canal for the facial nerve, and ends in that canal about 6 mm. above the stylomastoid foramen. Through it the chorda tympani nerve and a branch of the stylomastoid artery enter the tympanic cavity.

The *petrotympanic fissure* (Glaserian fissure) opens just above and in front of the ring of bone into which the tympanic membrane is inserted; in this situation it is a mere slit about 2 mm. in length. It lodges the anterior process and anterior ligament of the malleus, and transmits to the tympanic cavity the anterior tympanic branch of the internal maxillary artery.

The *iter chordæ anterius* (canal of Huguier) is placed at the medial end of the petrotympanic fissure; through it the chorda tympani nerve leaves the tympanic cavity.

The **tympanic membrane** (figs. 985, 986) separates the tympanic cavity from the external acoustic meatus. It is thin and semitransparent, nearly oval in form, somewhat broader above than below, and placed very obliquely, forming an angle of about fifty-five degrees with the floor of the meatus. Its longest diameter is downwards and forwards, and measures from 9 to 10 mm.; its shortest diameter from 8 to 9 mm. The greater part of its circumference is thickened, and forms a *fibrocartilaginous ring* which is fixed in the *tympanic sulcus* at the inner end of the meatus. This sulcus is deficient superiorly at the notch of Rivinus, and from the ends of this notch two bands, the *anterior* and *posterior malleolar folds*, are prolonged to the lateral process of the malleus. The small, somewhat triangular part of the membrane situated above these folds is lax and thin, and is named the *pars flaccida* (membrane of Shrapnell); a small orifice is sometimes seen in it. The chief part of the membrane is taut and is named the *pars tensa*. The manubrium of the malleus is firmly attached to the medial surface of the tympanic membrane as far as its centre, which projects towards the tympanic cavity; the medial surface of the membrane is thus convex, and the point of greatest convexity is named the *umbo*. Although the membrane as a whole is convex on its inner surface, its radiating fibres (vide infra) are curved with their concavities directed inwards, and the membrane has a shape somewhat resembling that of a convolvulus flower.

FIG. 986.—The membranous wall of the right tympanic cavity. (Testut.)



The malleus has been resected immediately below its lateral process, in order to show the malleolar folds and the pars flaccida.
1. Tympanic membrane. 2. Umbo. 3. Manubrium mallei; 4. its cut surface. 5. Anterior malleolar fold. 6. Posterior malleolar fold. 7. Pars flaccida. 8, 9. Anterior and posterior pouches of Tröltsch. 10. Fibrocartilaginous ring. 11. Petrotympanic fissure. 12. Auditory tube. 13. Iter chordæ posterius. 14. Iter chordæ anterius. 15. Fossa incudis for short crus of the incus. 16. Prominentia styloidea.

Structure.—The tympanic membrane is composed of three strata: a lateral (epidermal), an intermediate (fibrous), and a medial (mucous). The *epidermal stratum* is derived from the skin which lines the external acoustic meatus, and consists of stratified epithelium. The *fibrous stratum* consists of two layers: a superficial radiate stratum, the fibres of which diverge from the manubrium of the malleus, and a deep circular stratum, the fibres of which are plentiful around the circumference, but sparse and scattered near the centre, of the membrane. Branched or dendritic fibres (Grüber) are also present, especially in the posterior half of the membrane. The *mucous stratum* is a part of the mucous membrane of the tympanic cavity; it is thickest towards the upper part of the membrane, and is covered by a single layer of flattened cells. In the pars flaccida of the membrana tympani the fibrous stratum is replaced by loose connective tissue.

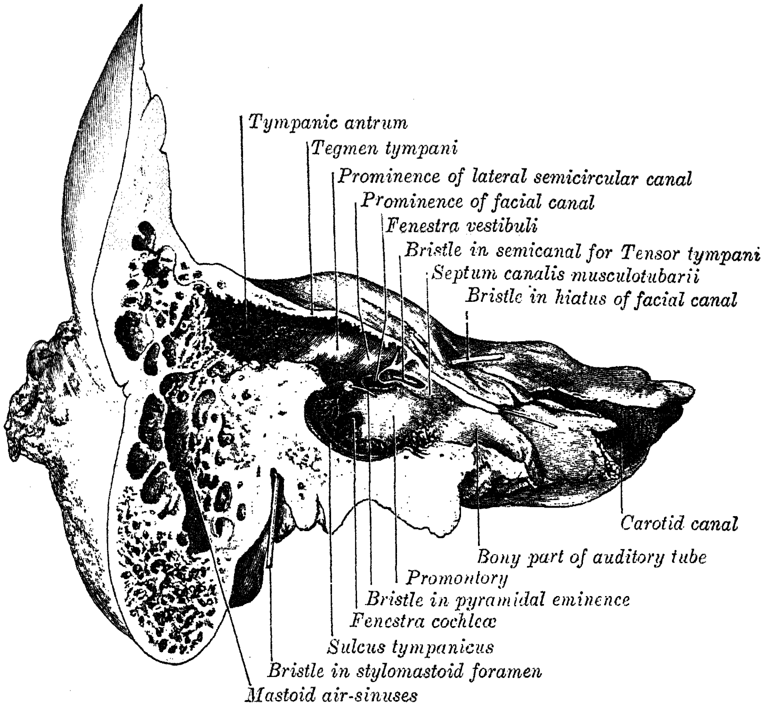
Vessels and Nerves.—The *arteries* of the tympanic membrane are derived from the deep auricular branch of the internal maxillary artery, which ramifies beneath the cutaneous stratum; and from the stylomastoid branch of the posterior auricular artery, and tympanic branch of the internal maxillary artery, which are distributed to the mucous

surface. The superficial *veins* open into the external jugular vein; those on the deep surface drain partly into the transverse sinus and veins of the dura mater, and partly into a plexus of veins on the auditory tube. The membrane receives its *nerve-supply* from the auriculotemporal branch of the mandibular nerve, the auricular branch of the vagus nerve, and the tympanic branch of the glossopharyngeal nerve.

The **labyrinthic or medial wall** (fig. 987) of the tympanic cavity is formed by the lateral wall of the internal ear. It presents for examination the fenestra vestibuli, the fenestra cochleæ, the promontory, and the prominence of the facial canal.

The *fenestra vestibuli* (fenestra ovalis) is a reniform opening, situated above and behind the promontory, and leading from the tympanic cavity into the vestibule of the internal ear; its long diameter is horizontal, and its convex

FIG. 987.—A coronal section through the right temporal bone. Anterior aspect.



border is upwards. In the recent state it is occupied by the base of the stapes, the circumference of which is fixed to the margin of the fenestra by the ligamentum annulare baseos stapedis.

The *fenestra cochleæ* (fenestra rotunda) is situated below and a little behind the fenestra vestibuli, from which it is separated by the promontory. It lies completely under cover of the overhanging edge of the promontory, in a deep hollow or niche. It is placed very obliquely, and, in the macerated bone, opens upwards and forwards from the tympanic cavity into the scala tympani of the cochlea. In the recent state it is closed by the *secondary tympanic membrane*, which is somewhat concave towards the tympanic cavity, and convex towards the cochlea, the membrane being bent so that its postero-superior one-third forms an angle with its antero-inferior two-thirds. This membrane consists of three layers: an external, derived from the mucous lining of the tympanic cavity; an internal, from the lining membrane of the cochlea; and an intermediate, fibrous layer.

The *promontory* is a rounded prominence, formed by the projection outwards of the first turn of the cochlea; it is placed between the fenestra vestibuli and fenestra cochleæ, and its surface is furrowed by small grooves which lodge

the nerves of the tympanic plexus. A minute spicule of bone frequently connects the promontory to the pyramidal eminence.

The *prominence of the facial canal* indicates the position of the upper part of the bony canal (aquæductus Fallopii), in which the facial nerve is contained; this canal, the wall of which may be partly deficient, traverses the labyrinthic wall of the tympanic cavity from before backwards, immediately above the fenestra vestibuli, and then curves downwards in the mastoid wall.

The **mastoid or posterior wall** of the tympanic cavity is wider above than below, and presents for examination the entrance to the tympanic antrum, the pyramidal eminence, and the fossa incudis.

The *entrance to the antrum* (aditus ad antrum) is a large irregular aperture, which leads backwards from the epitympanic recess into an air-sinus, named the *tympanic or mastoid antrum* (p. 209). The antrum communicates behind and below with the *mastoid air-sinuses,* which vary considerably in number, size, and form; the antrum and mastoid air-sinuses are lined by mucous membrane, continuous with that lining the tympanic cavity. On the medial wall of the entrance to the antrum is a rounded eminence, situated above and behind the prominence of the facial canal; it corresponds with the position of the lateral semicircular canal.

The *pyramidal eminence* is situated immediately behind the fenestra vestibuli, and in front of the vertical portion of the facial canal; it is hollow, and contains the Stapedius muscle; its summit projects forwards towards the fenestra vestibuli, and is pierced by a small aperture which transmits the tendon of the muscle. The cavity in the pyramidal eminence is prolonged downwards and backwards in front of the facial canal, and communicates with the latter by a minute aperture which transmits a twig from the facial nerve to the Stapedius muscle.

The *fossa incudis* is a small depression in the lower and posterior part of the epitympanic recess; it lodges the short crus of the incus, which is fixed to the fossa by ligamentous fibres.

The **carotid or anterior wall** of the tympanic cavity is narrowed in its vertical diameter by the descent of the tegmen tympani; it is separated from the carotid canal by a thin plate of bone perforated by the tympanic branch of the internal carotid artery, and by the caroticotympanic nerves. At the upper part of the anterior wall are the orifice of the semicanal for the Tensor tympani, and the tympanic orifice of the auditory tube, separated from each other by a thin horizontal plate of bone, the septum canalis musculotubarii. These canals run from the tympanic cavity forwards and downwards to the angle of union between the squama and the petrous portion of the temporal bone.

The *semicanal for the Tensor tympani,* the higher and smaller semicanal, is cylindrical and lies beneath the tegmen tympani. It extends on to the labyrinthic wall of the tympanic cavity, and ends immediately above the fenestra vestibuli.

The *septum canalis musculotubarii* (processus cochleariformis) passes backwards below this semicanal, forming its lateral wall and floor; it expands above the anterior end of the fenestra vestibuli, and terminates there by curving laterally so as to form a pulley over which the tendon of the muscle passes.

The **auditory tube** (Eustachian tube) is the channel through which the tympanic cavity communicates with the nasal part of the pharynx. Its length is about 36 mm., and its direction is downwards, forwards, and medialwards, forming an angle of about 45° with the sagittal plane and one of about 30° with the horizontal plane. It is formed partly of bone, partly of cartilage and fibrous tissue (fig. 983).

The *osseous portion* is about 12 mm. long. It begins in the carotid or anterior wall of the tympanic cavity, below the septum canalis musculotubarii, and, gradually narrowing, ends at the angle of junction of the squama and the petrous portion of the temporal bone, its extremity presenting a jagged margin which serves for the attachment of the cartilaginous portion. It is oblong in transverse section with its greater diameter from side to side. It lies immediately above the carotid canal, from which it is separated by a very thin plate of bone.

The *cartilaginous portion,* about 24 mm. long, is formed of a triangular plate of elastic fibrocartilage, the greater part of which is situated in the medial wall of the tube. The apex of the fibrocartilage is attached by fibrous tissue to the circumference of the medial end of the osseous portion of the tube, while

its base lies directly under the mucous membrane of the lateral wall of the nasal part of the pharynx, where it forms an elevation, the *torus tubarius* or *cushion*, behind the pharyngeal orifice of the tube. The upper part of the cartilage is bent lateralwards and downwards, and the cartilage therefore consists of a broad *lamina medialis*, and a narrow *lamina lateralis*. On transverse section the cartilage has the appearance of a hook; a groove or furrow is thus produced, which is open below and laterally, and this part of the wall of the canal is completed by fibrous membrane. The cartilage is fixed to the base of the skull in a groove between the petrous part of the temporal bone and the great wing of the sphenoidal bone; this groove ends opposite the middle of the medial pterygoid lamina. The cartilaginous and bony portions of the tube are not in the same plane, the former inclining downwards a little more than the latter. The diameter of the tube is not uniform throughout, being greatest at the pharyngeal orifice, least at the junction of the bony and cartilaginous portions, and again increased towards the tympanic cavity; the narrowest part of the tube is termed the *isthmus*. The position and relations of the pharyngeal orifice are described with the nasal part of the pharynx (p. 1122). The mucous membrane of the tube is continuous in front with that of the nasal part of the pharynx, and behind with that of the tympanic cavity; it is covered with ciliated columnar epithelium and is thin in the osseous portion, while in the cartilaginous portion it contains many mucous glands, and near the pharyngeal orifice a considerable amount of adenoid tissue, named by Gerlach the *tube-tonsil*. The tube is opened during deglutition by the Salpingopharyngeus and Dilatator tubæ. The latter arises from the lateral lamina of the cartilage and from the membranous part of the tube, and blends below with the Tensor veli palatini. H. Blakeway * is of opinion that contraction of the Tensor veli palatini is more likely to produce closure than opening of the tube.

In the new-born child the auditory tube is about half as long as that of the adult. Its direction is more horizontal, and its osseous portion is relatively shorter but much wider than in the adult. Its pharyngeal orifice is a narrow slit which is on a level with the palate, and is devoid of a torus tubarius.

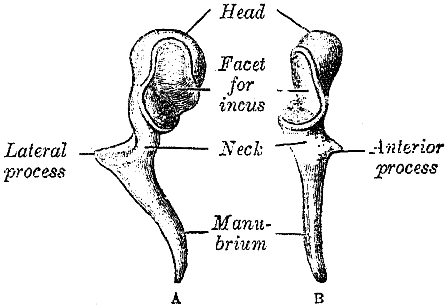
Vessels and Nerves.—The *arteries* of the auditory tube are derived from the ascending pharyngeal branch of the external carotid artery and from two branches of the internal maxillary artery, viz.:—the middle meningeal artery and the artery of the pterygoid canal. The *veins* open into the pterygoid venous plexus. The *nerves* of the tube spring from the pharyngeal plexus and from the pharyngeal branch of the sphenopalatine ganglion.

The Auditory Ossicles

The tympanic cavity contains a chain of three movable ossicles, the *malleus*, *incus*, and *stapes*. The malleus is attached to the tympanic membrane, the stapes to the circumference of the fenestra vestibuli, while the incus is placed between the malleus and stapes and connected to them by delicate articulations.

The **malleus** (fig. 988), so named from its fancied resemblance to a hammer, is from 8 to 9 mm. long, and is the largest of the auditory ossicles. It consists of a head, neck, and three processes, viz. the manubrium, and the anterior and lateral processes.

Fig. 988.—The left malleus. A. From behind. B. From within.



The *head*, the large upper end of the bone, is situated within the epitympanic recess; it is ovoid in shape and articulates posteriorly with the incus, being free in the rest of its extent. The facet for articulation with the incus is constricted near the middle, and consists of an upper larger and lower smaller part, situated nearly at right angles to one another.

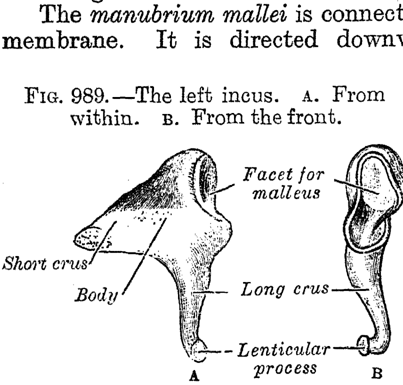
* *Journal of Anatomy and Physiology*, vol. xlviii.

Opposite the constriction the lower margin of the facet projects in the form of a process, the *cog-tooth* or *spur* of the malleus.

The *neck* is the contracted part just beneath the head; below the neck is an enlargement to which the various processes are attached.

The *manubrium mallei* is connected by its lateral margin with the tympanic membrane. It is directed downwards, medialwards, and backwards; it decreases in size towards its free end, which is curved slightly forwards and flattened transversely. Near the upper end of its medial surface is a slight projection, into which the tendon of the Tensor tympani is inserted.

Fig. 989.—The left incus. A. From within. B. From the front.



The *anterior process* (processus gracilis) is a delicate spicule, directed forwards from the enlargement below the neck; it is connected to the petrotympanic fissure by ligamentous fibres. In the fœtus this is the longest process of the malleus, and is continuous in front with the cartilage of Meckel (p. 77).

The *lateral process* (processus brevis) is a conical projection, which springs from the root of the manubrium; it is directed laterally, and is attached to the upper part of the tympanic membrane and, by means of the anterior and posterior malleolar folds, to the extremities of the notch of Rivinus.

Ossification.—The malleus, with the exception of its anterior process, is ossified from a single centre which appears near the neck of the bone. The anterior process is ossified separately, in membrane, and joins the main part of the bone about the sixth month of fœtal life.

The **incus** (fig. 989) has received its name from its supposed resemblance to an anvil, but its shape is more like that of a premolar tooth, with two widely diverging roots. It consists of a body and two crura.

The *body* is somewhat cubical, but compressed transversely. On its anterior surface is a saddle-shaped facet, for articulation with the head of the malleus.

The two crura diverge from one another nearly at right angles.

The *short crus*, somewhat conical in shape, projects backwards, and is attached by ligamentous fibres to the fossa incudis, in the lower and posterior part of the epitympanic recess.

The *long crus*, rather more than half the length of the manubrium mallei, descends nearly vertically behind and parallel to that process; its lower end bends medialwards, and terminates in a rounded projection, the *lenticular process*, the inner surface of which is covered with cartilage, and articulates with the head of the stapes.

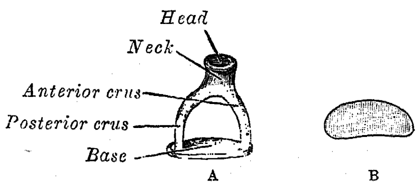
Ossification.—The incus is ossified from one centre which appears in the upper part of its long crus.

The **stapes** (fig. 990), so called from its resemblance to a stirrup, consists of a head, neck, two crura, and a base.

On the *head*, which is directed lateralwards, is a depression for articulation with the lenticular process of the incus.

On the *neck* or constricted part succeeding the head, the tendon of the Stapedius muscle is inserted.

Fig. 990.—A. The left stapes. B. Medial surface of the base of the stapes.



The *crura* diverge from the neck and are connected at their ends by a flattened oval plate, the *base*, which forms the footplate of the stirrup and is fixed to the margin of the fenestra vestibuli by a ring of ligamentous fibres. The anterior crus is shorter and less curved than the posterior.

Ossification.—The stapes is ossified from a single centre which appears in the base of the bone.

The **articulations of the auditory ossicles.**—The incudomalleolar joint is a saddle-shaped diarthrosis; it is surrounded by an articular capsule,

and the joint-cavity is incompletely divided by a wedge-shaped articular disc or meniscus. The incudostapedial joint is an enarthrosis, surrounded by an articular capsule; some observers have described an articular disc or meniscus in this joint; others regard the joint as a syndesmosis.

The **ligaments of the ossicles.**—The ossicles are connected to the walls of the tympanic cavity by ligaments: three for the malleus, and one each for the incus and stapes.

The *anterior ligament of the malleus* is attached by one end to the neck of the malleus, just above the anterior process, and by the other to the anterior wall of the tympanic cavity, close to the petrotympanic fissure, some of its fibres being prolonged through the fissure, to reach the spina angularis of the sphenoidal bone.

The *lateral ligament of the malleus* is a triangular band passing from the posterior part of the border of the notch of Rivinus to the head of the malleus. Helmholtz described the anterior ligament and the posterior part of the lateral ligament as forming together the 'axis ligament' around which the malleus rotates.

The *superior ligament of the malleus* connects the head of the malleus to the roof of the epitympanic recess.

The *posterior ligament of the incus* connects the end of the short crus of the incus to the fossa incudis.

A *superior ligament of the incus* has been described, but it is little more than a fold of mucous membrane.

The vestibular surface and the circumference of the base of the stapes are covered with hyaline cartilage; that encircling the base is attached to the margin of the fenestra vestibuli by a ring of elastic fibres, the *ligamentum annulare baseos stapedis*. The posterior part of this ligament is much narrower than the anterior part, and acts as a kind of hinge on which the base of the stapes moves when the Stapedius muscle contracts.

Movements of the auditory ossicles.—The manubrium mallei follows all the movements of the tympanic membrane, while the malleus and incus rotate together around an axis which runs through the short crus of the incus and the anterior ligament of the malleus. When the tympanic membrane and manubrium mallei are propelled inwards the long crus of the incus also moves in the same direction and pushes the base of the stapes towards the labyrinth. This motion is communicated to the fluid (perilymph) contained within the labyrinth and the movement of the perilymph causes an outward bulging of the secondary tympanic membrane which closes the fenestra cochleæ. The conditions are reversed when the tympanic membrane moves in a lateral direction, but if this movement of the membrane be exaggerated the incus does not follow the full outward excursion of the malleus, but merely glides on this bone at the incudomalleolar joint, and thus the danger of pulling the foot of the stapes out of the fenestra vestibuli is prevented. When the manubrium mallei is carried inwards the cog-tooth or spur on the lower margin of the head of the malleus locks the incudomalleolar joint, and this necessitates an inward movement of the long crus of the incus; the joint is unlocked when the manubrium mallei is carried outwards.

The **muscles of the tympanic cavity** are the Tensor tympani and Stapedius.

The **Tensor tympani** is contained in the bony canal above the osseous portion of the auditory tube, from which it is separated by the septum canalis musculotubarii. It arises from the cartilaginous portion of the auditory tube and the adjoining part of the great wing of the sphenoidal bone, as well as from the osseous canal in which it is contained. Passing backwards through the canal, it ends in a slender tendon which bends lateralwards round the pulley-like posterior end of the septum, and is inserted into the manubrium mallei, near its root.

Nerve-supply.—The Tensor tympani is supplied by a branch of the mandibular nerve through the otic ganglion.

Action.—The Tensor tympani draws the manubrium mallei medialwards, and as a consequence the base of the stapes is pushed inwards, thus increasing the pressure of the fluid in the labyrinth.

The **Stapedius** arises from the wall of a conical cavity in the pyramidal eminence; its tendon emerges from the orifice at the apex of the eminence, and, passing forwards, is inserted into the posterior surface of the neck of the stapes.

Nerve-supply.—The Stapedius is supplied by a branch of the facial nerve.

Action.—The Stapedius pulls the head of the stapes backwards, and tilts the anterior end of the base towards the tympanic cavity, thus diminishing the pressure of the fluid in the labyrinth. The Stapedius, therefore, counteracts the action of the Tensor tympani.

The **mucous membrane of the tympanic cavity** is continuous with that of the pharynx, through the auditory tube. It invests the auditory ossicles and the muscles and nerves contained in the tympanic cavity, forms the medial layer of the tympanic membrane, and the lateral layer of the secondary tympanic membrane, and lines the tympanic antrum and mastoid air-sinuses. It forms several vascular folds, which extend from the walls of the tympanic cavity to the ossicles; of these, one descends from the roof of the cavity to the head of the malleus and upper margin of the body of the incus, a second invests the Stapedius muscle; other folds invest the chorda tympani nerve and the Tensor tympani muscle. These folds separate off pouch-like cavities, and give the interior of the tympanum a somewhat honeycombed appearance. One of these pouches, the *pouch of Prussak*, lies between the neck of the malleus and the membrana flaccida. Two other recesses, the *anterior and posterior recesses of Tröltsch*. may be mentioned: they are formed by the mucous membrane which envelops the chorda tympani nerve, and are situated, one in front of, and the other behind, the manubrium mallei. In the tympanic cavity the mucous membrane is pale, thin, slightly vascular, and covered with cubical epithelial cells, except around the orifice of the auditory tube, where the cells are ciliated. There are no mucous glands in the tympanic cavity. The tympanic antrum and the mastoid air-sinuses are lined by squamous, non-ciliated epithelium.

Vessels and Nerves.—The *arteries* are six in number. Two of them are larger than the others, viz. the anterior tympanic branch of the internal maxillary artery, which supplies the tympanic membrane, and the stylomastoid branch of the posterior auricular artery, which supplies the posterior part of the tympanic cavity and mastoid air-sinuses. The smaller arteries are—the petrosal branch of the middle meningeal artery, which enters through the hiatus of the facial canal; a branch from the ascending pharyngeal artery, and another from the artery of the pterygoid canal, which accompany the auditory tube; and the tympanic branch from the internal carotid artery, given off in the carotid canal and perforating the thin anterior wall of the tympanic cavity. The *veins* terminate in the pterygoid venous plexus and in the superior petrosal sinus. From the mucous membrane of the tympanic antrum a small group of veins runs medialwards through the arch formed by the superior semicircular canal. They emerge on the posterior surface of the petrous part of the temporal bone through the subarcuate fossa, and open into the superior petrosal sinus. These small veins are the remains of the large subarcuate veins of the child, and constitute a pathway of infection from the tympanic antrum to the meninges of the brain. The *nerves* constitute the tympanic plexus, which ramifies upon the surface of the promontory. The plexus is formed by (1) the tympanic branch of the glossopharyngeal nerve, and (2) the caroticotympanic nerves.

The *tympanic branch of the glossopharyngeal* (Jacobson's nerve) enters the tympanic cavity by the inferior tympanic canaliculus, and divides into branches which ramify on the promontory and enter into the formation of the tympanic plexus. The *superior and inferior caroticotympanic nerves*, from the carotid plexus of the sympathetic, pass through the wall of the carotid canal, and join the plexus. The tympanic plexus supplies, (*a*) branches to the mucous lining of the tympanic cavity, auditory tube, and mastoid air-sinuses; (*b*) a branch which goes through an opening in front of the fenestra vestibuli and joins the greater superficial petrosal nerve; and (*c*) the *lesser superficial petrosal nerve*, which may be looked upon as the continuation of the tympanic branch of the glossopharyngeal nerve through the tympanic plexus. The lesser superficial petrosal nerve traverses a small canal beneath the semicanal for the Tensor tympani, runs past, and receives a connecting branch from, the genicular ganglion of the facial nerve, and reaches the anterior surface of the temporal bone through a small opening on the lateral side of the hiatus of the facial canal. It then passes through the foramen ovale or the canaliculus innominatus of Arnold (p. 203 *) and joins the otic ganglion (p. 903).

The *chorda tympani nerve* crosses the tympanic cavity. It is given off from the sensory part of the facial nerve, about 6 mm. before that nerve emerges from the stylomastoid foramen. It runs upwards and forwards in a canal, and enters the tympanic cavity through the *iter chordæ posterius*, and becomes invested with mucous membrane. It traverses the tympanic cavity, crossing medial to the tympanic membrane and the upper part of the manubrium mallei to the carotid wall, where it emerges through the *iter chordæ anterius*, or *canal of Huguier*.

Applied Anatomy.—Fractures of the middle fossa of the base of the skull almost invariably involve the tympanic roof, and are accompanied by a rupture of the tympanic

membrane or fracture through the roof of the bony meatus. They are associated with profuse continued bleeding from the ear, and, if the dura mater has also been torn, with discharge of copious amounts of cerebrospinal fluid. Here the avoidance of infection from the outside is of the utmost importance, as should it occur septic meningitis must inevitably follow with a fatal issue.

The tympanic cavity is very frequently the seat of disease, both suppurative and non-suppurative, and in practically every case the inflammation spreads upwards from the nose or throat along the auditory tube. Acute inflammatory troubles spreading up to the tympanic cavity are usually associated with so much inflammatory swelling of the mucous membrane of the auditory tube as to occlude it, and thus the products of inflammation are pent up in the tympanic cavity and directly involve the tympanic antrum. Under such circumstances the only means of escape for the products is by rupture of the tympanic membrane, which usually occurs spontaneously and is followed by a free discharge of pus, with relief from the acute pain which exists in this condition. Should the swelling of the walls of the auditory tube then subside, the normal drainage of the cavity will be established and the perforation in the drum will heal, but if not—as is often the case because the opening of the tube may be occluded by adenoid growths in the nasopharynx or other cause—the pus will continue to accumulate in the middle ear and will overflow through the perforation as a chronic otorrhœa. In the course of time the disease spreads beyond the mucous membrane to the walls of the tympanic cavity, to the ossicles, or to the mastoid process, and when this has occurred the condition is incurable except by the removal of the carious bone. Further, severe intracranial complications are at this time often produced owing to purulent material being retained; thus an abscess may form between the bone and dura mater, (*a*) about the roof of the tympanic cavity, and immediately beneath the dura covering the temporal lobe, or (*b*) between the deep aspect of the mastoid process and the sigmoid bend of the transverse sinus, possibly extending widely and surrounding the sinus. In this latter type of case thrombosis of the transverse sinus readily occurs, and the clot being also infected tends to disintegrate and be carried into the general circulation, particles becoming lodged in the capillaries of the lungs and setting up abscesses therein. Pyæmia from transverse sinus thrombosis is more common than from any other focus of origin. In addition, bone disease of the tympanic cavity or antrum may be associated with severe and fatal septic meningitis, or with the formation of abscess in the brain, the most common sites being the temporal lobe and the hemisphere of the cerebellum.

Less serious, but more common, is the formation of a subperiosteal mastoid abscess with great swelling behind the ear, and protrusion outwards of the auricula; such a condition demands an early incision through all the structures, including the periosteum, over the whole length of the mastoid process, and then it will frequently be found that the underlying bone is carious or that a track leads through the bone into the tympanic antrum. In such conditions extensive operations for the removal of bone are often required. In many cases of chronic bone disease in the tympanic cavity, the facial nerve becomes exposed as it lies in its canal, and an inflammatory process is set up in the nerve, leading to facial paralysis of the infranuclear type (p. 912). In other cases localised areas of bone disease, most often in the region of the epitympanic recess, form the points from which aural polypi grow, and the ear polypus, like the nasal polypus, must be considered to have originated in a spot of carious bone, the removal of which is necessary if a cure is to be established.

In dealing with suppuration in the tympanum by operation, the tympanic antrum is first reached through the suprameatal triangle of Macewen (page 206), the posterior wall of the external acoustic meatus being the direction which is taken. In enlarging the opening from the antrum to the tympanum, the facial nerve is protected by passing a special probe through the passage, and only removing the bone from the lateral side. In the child the tympanic antrum is close to the surface, and the facial nerve is not covered by the mastoid process.

Of the non-suppurative conditions which affect the middle ear, chronic catarrh, leading to sclerosis of the whole of the tympanic contents, is again due to spread of inflammation from some nasal or pharyngeal condition. The progress is very slow, but leads to ever-increasing deafness—this deafness in the first instance is in no way connected with any defect in the acoustic nerve, and this can be shown by the fact that the hearing by bone conduction over the mastoid process remains normal or is increased. In chronic non-suppurative otitis media, treatment must be especially directed towards placing the nose and pharynx in a healthy condition; when this has been accomplished, the aural condition often improves of itself; if not, improvement may be induced by forcing air up the auditory tube by means of the Politzer bag, or directly into the orifice of the tube by means of a catheter.

Internal Ear, or Labyrinth

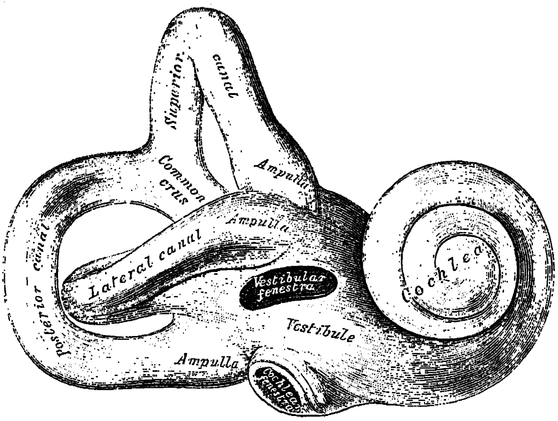
The **internal ear** or **labyrinth** is the essential part of the organ of hearing. It consists of two parts: (*a*) the *osseous labyrinth*, a series of cavities within the petrous part of the temporal bone, and (*b*) the *membranous labyrinth*, a

series of communicating membranous sacs and ducts, contained within the bony cavities.

THE OSSEOUS LABYRINTH (figs. 991, 992)

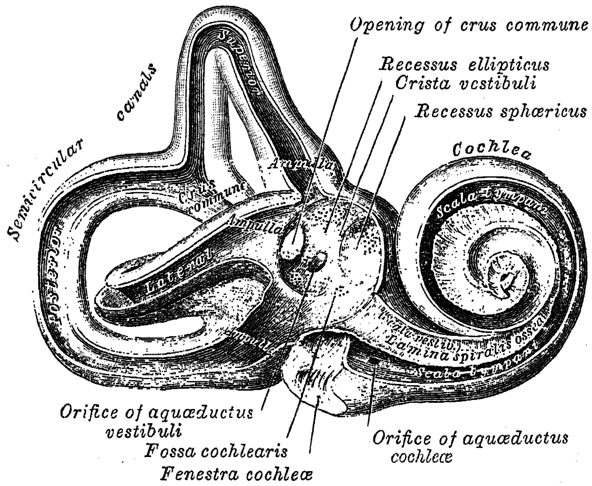
The **osseous labyrinth** consists of three parts: the *vestibule*, the *semicircular canals*, and the *cochlea*. These are cavities hollowed out of the substance of the bone, and lined by periosteum; they contain a clear fluid, the perilymph, in which the membranous labyrinth is placed.

FIG. 991.—The right osseous labyrinth. Lateral aspect.



The **vestibule** is the central part of the osseous labyrinth, and is situated medial to the tympanic cavity, behind the cochlea, and in front of the semicircular canals. It is somewhat ovoid in shape, but flattened transversely; it measures about 5 mm. from before backwards, the same from above downwards, and about 3 mm. across. In its *lateral or tympanic wall* is the fenestra vestibuli, closed in the recent state by the base of the stapes and its annular ligament. On the front part of the *medial wall* is a small circular depression, the *recessus sphœricus*, which lodges the saccule, and is perforated by several minute holes (*macula cribrosa media*) for the passage of filaments of the acoustic nerve to the saccule. Behind this recess is an oblique ridge, the *crista vestibuli*, the anterior end of which is named the *pyramid of the vestibule*; this ridge divides below to enclose a small depression, the *fossa cochlearis*, which is perforated by a number of holes for the passage of filaments of the acoustic nerve to the vestibular end of the ductus cochlearis. At the hinder part of the medial wall is the orifice of the *aquæductus vestibuli*. This aqueduct extends to the posterior surface of the petrous portion of the temporal bone; it transmits a small vein, and contains a tubular prolongation of the membranous labyrinth, the *ductus endolymphaticus*. Above and behind the crista vestibuli, and situated in the *roof* and medial wall of the vestibule is an elliptical depression, the *recessus ellipticus*, which lodges the utricle. The pyramid and adjoining part of the recessus ellipticus are perforated by a number of holes (*macula cribrosa superior*); the holes in the pyramid transmit the nerves to the utricle, and those in the recessus ellipticus the nerves to the ampullæ of the superior and lateral semicircular ducts. At the *posterior part* of the vestibule there are

FIG. 992.—The interior of the right osseous labyrinth.



the five orifices of the semicircular canals; at the *anterior part* is an elliptical opening leading into the scala vestibuli of the cochlea.

The **bony semicircular canals** are three in number, superior, posterior and lateral, and are situated above and behind the vestibule. They are compressed from side to side, and each describes about two-thirds of a circle. They are unequal in length, but are about 0·8 mm. in diameter and each presents a dilatation at one end, called the *ampulla*, the diameter of which is nearly twice that of the canal. They open into the vestibule by five orifices, one of which is common to two of the canals.

The *superior semicircular canal*, 15 to 20 mm. in length, is vertical in direction, and is placed transversely to the long axis of the petrous portion of the temporal bone, on the anterior surface of which its arch forms a round projection. Its antero-lateral end is ampullated, and opens into the upper and lateral part of the vestibule; the opposite end unites with the upper end of the posterior canal to form the *crus commune*, which is about 4 mm. long, and opens into the medial part of the vestibule.

The *posterior semicircular canal*, also vertical, is directed backwards, nearly parallel to the posterior surface of the petrous bone; it is from 18 mm. to 22 mm. long; its ampullated end opens into the lower part of the vestibule, where there are several small holes (*macula cribrosa inferior*) for the transmission of the nerves to this ampulla. Its upper end opens into the crus commune.

The *lateral or horizontal canal* is from 12 mm. to 15 mm. long, and its arch is directed horizontally backwards and lateralwards. Its anterior or ampullated end opens into the upper and lateral angle of the vestibule, just above the fenestra vestibuli and close to the ampullated end of the superior canal; its posterior end opens below the orifice of the crus commune.

The lateral semicircular canal of one ear is in the same plane as that of the other ear; while the superior canal of one ear is in a plane parallel with that of the posterior canal of the other ear.

The **cochlea** (figs. 992, 993) bears a resemblance to the shell of the common snail; it forms the anterior part of the labyrinth, is conical in form, and placed in front of the vestibule; it measures about 5 mm. from base to apex, and its breadth across the base is about 9 mm. Its apex (*cupula*) is directed forwards and lateralwards, with a slight inclination downwards, towards the upper and front part of the labyrinthic wall of the tympanic cavity; its base corresponds with the bottom of the internal acoustic meatus, and is perforated by numerous apertures for the passage of the cochlear nerve. The cochlea * consists of a conical-shaped central axis, the *modiolus*; of a canal, wound spirally around the central axis for two turns and three-quarters; and of a delicate lamina, the *osseous spiral lamina*, which projects from the modiolus into the canal, and partially subdivides it. In the recent state the subdivision of the canal is completed by the *basilar membrane* which stretches from the free border of the osseous spiral lamina to the outer wall of the bony cochlea; the two passages into which the cochlear canal is thus divided communicate with each other at the apex of the modiolus by a small opening, named the *helicotrema*.

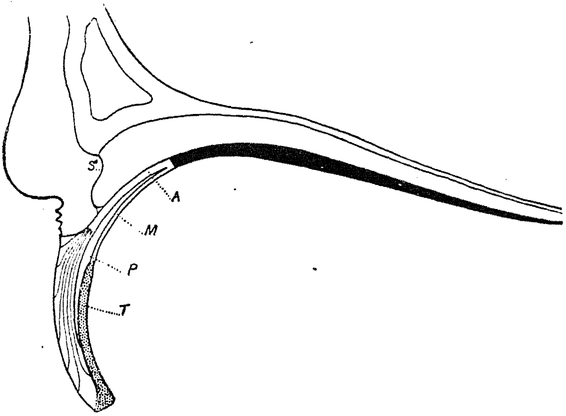
The *modiolus* is the conical central axis or pillar of the cochlea. Its base is broad, and appears at the bottom of the internal acoustic meatus, where it corresponds with the tractus spiralis foraminosus which is perforated by numerous orifices, for the transmission of the branches of the cochlear nerve; the nerves for the first turn and a half of the cochlea pass through the foramina of the tractus spiralis foraminosus; those for the apical turn, through the foramen centrale. The canals of the tractus spiralis foraminosus pass up through the modiolus and successively bend outwards to reach the attached margin of the osseous spiral lamina. Here they become enlarged, and by their apposition form the *spiral canal of the modiolus*, which follows the course of the attached margin of the osseous spiral lamina and lodges the spiral ganglion (ganglion of Corti). The foramen centrale is continued into a canal which runs up the middle of the modiolus to its apex. The modiolus diminishes rapidly in size in the second and succeeding coil.

The bony canal of the cochlea takes two turns and three-quarters round the modiolus. It is about 30 mm. long, and diminishes gradually in diameter

* In the description which follows, the cochlea is supposed to be resting on its base.

orbital margin p. 240). Deep to this attachment is that of the lateral palpebral ligament which fixes the tarsal plates to the same tubercle. When traced medially the aponeurosis loses its tendinous nature as it passes over and comes into close contact with the reflected tendon of the Obliquus superior, whence it can be followed with difficulty towards the medial palpebral ligament in the form of loose strands of connective tissue. When the

Fig. 967.—A diagram of the Levator palpebræ superioris, showing its connexions. (*From Whitnall's "Anatomy of the human orbit"*; Oxford Medical Publications.)

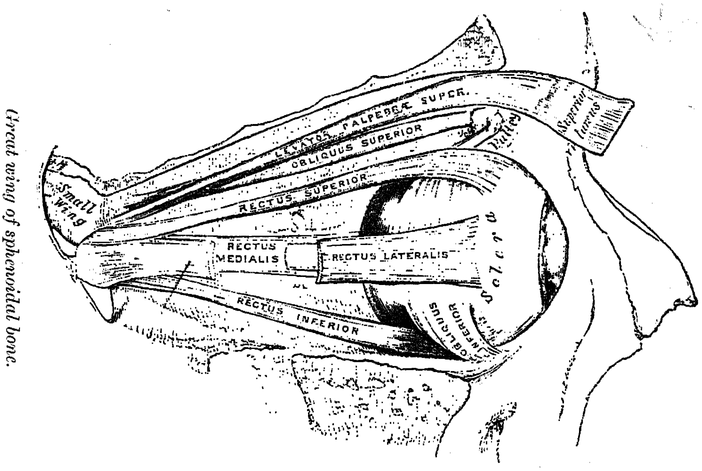


A, Superficial lamella of aponeurosis; *M*. Deep lamella (Müller's muscle); *P*, Pretarsal space; *T*, Tarsus; *S*. Orbital septum.

Levator palpebræ contracts the upper eyelid is raised, but the lateral and medial parts of the aponeurosis are stretched and limit the action of the muscle; the elevation of the upper eyelid is checked also by the orbital septum.

The **four Recti** (figs. 968, 969) arise from the annulus tendineus communis, a fibrous ring which surrounds the upper, medial, and lower margins of the

Fig. 968.—The muscles of the right orbit. Lateral aspect.



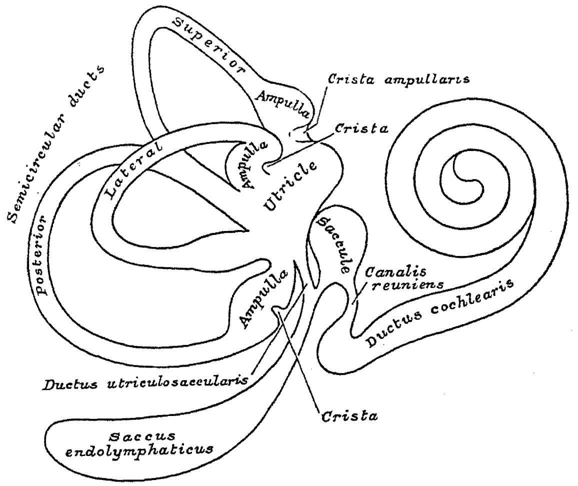
optic foramen (fig. 969); it is completed by a tendinous band which bridges the lower and medial part of the superior orbital fissure and is attached to a tubercle on the margin of the great wing of the sphenoidal bone. The ring is

perilymph, a fluid identical in composition, and confluent with, the cerebrospinal fluid. The part of the petrous bone which immediately surrounds the labyrinth is developed from the cartilaginous ear-capsule; it is denser than the rest of the petrous bone, and exhibits interglobular spaces, which contain cartilage cells (fig. 997). The modiolus of the cochlea, on the other hand, is formed of spongy membrane-bone (Fraser and Dickie *). A tubular process of the lining membrane is prolonged through the aquæductus cochleæ to the inner surface of the dura mater.

The Membranous Labyrinth (figs. 994, 995, 996)

The **membranous labyrinth** is lodged within the bony labyrinth; it is filled with fluid named *endolymph*, and in its walls the branches of the acoustic nerve are distributed. It consists of: (*a*) two small sacs, the *utricle* and *saccule*, lodged in the vestibule; (*b*) three *semicircular ducts*, enclosed within the semicircular canals; and (*c*) the *ductus cochlearis*, contained within the bony cochlea. The various parts of the membranous labyrinth form a closed system of channels which, however, communicate freely with one another; the semicircular ducts open into the utricle, the utricle into the saccule through the ductus endolymphaticus, and the saccule into the ductus cochlearis through the canalis reuniens of Hensen.

Fig. 994.—A schematic representation of the membranous labyrinth. (J. K. Milne Dickie.)



The membranous labyrinth is fixed at certain points to the wall of the bony labyrinth, but is separated from the greater part of the bony labyrinth by a space which contains the *perilymph*. The perilymphatic space of the vestibule communicates behind with that of the semicircular canals, and opens anteriorly into the scala vestibuli of the cochlea, which in turn opens into the scala tympani through the helicotrema, at the apex of the cochlea. The scala tympani is separated from the tympanic cavity by the secondary tympanic membrane, but is continuous with the subarachnoid cavity through the aquæductus cochleæ.

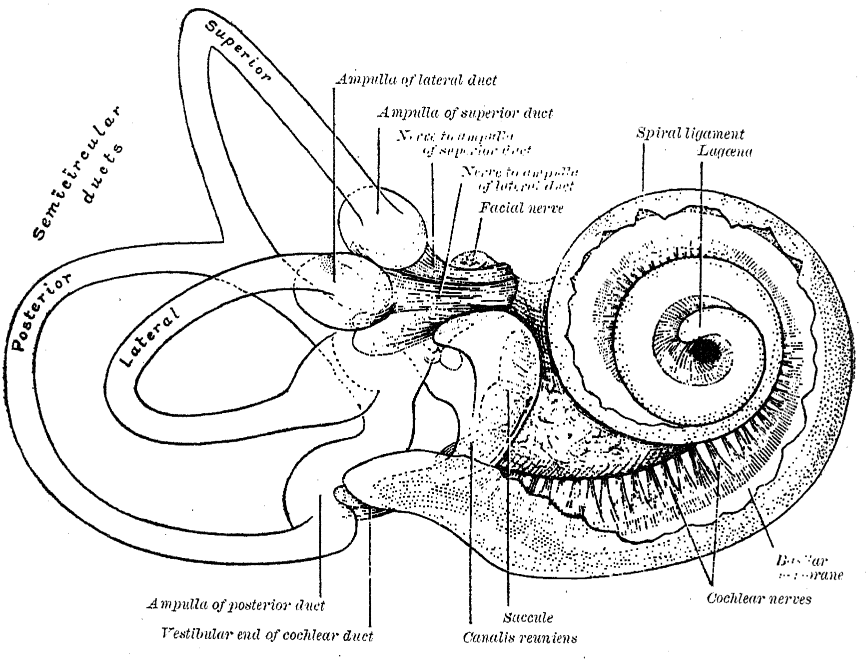
The **utricle**, the larger of the two vestibular sacs, is irregularly oblong in shape, and occupies the upper and posterior part of the vestibule, lying in contact with the recessus ellipticus and the part below it. That portion which is lodged in the recessus ellipticus forms a sort of pouch or cul-de-sac; the lateral half of the floor of this is thickened, and forms the *macula acustica utriculi*, which receives the utricular filaments of the acoustic nerve. The ampullæ of the superior and lateral semicircular ducts open into the lateral part of the utricle, while the ampulla of the posterior duct, the crus commune, and the posterior end of the lateral duct open into the medial part of the utricle. The posterior end of the lateral duct widens into a flattened cone which joins the medial end of the utricle at a right angle (Milne Dickie †). From its anteromedial part a fine canal, the *ductus utriculosaccularis*, is given off, and opens into the ductus endolymphaticus.

* J. S. Fraser and J. K. Milne Dickie, *Journal of Anatomy and Physiology*, vol. xlix.

† J. K. Milne Dickie, *Journal of Laryngology, Rhinology and Otology*, vol. xxxv.

The **saccule** lies in the recessus sphæricus near the opening of the scala vestibuli of the cochlea. When seen from the front it presents a nearly globular form, but it is prolonged backwards in the form of a cone, the upper surface of which is in contact with the under surface of the utricle, and utricle and saccule have here a common wall (Milne Dickie *). On its anterior wall is an oval thickening, the *macula acustica sacculi* (fig. 998), to which the saccular filaments of the acoustic nerve are distributed. Its cavity communicates indirectly through a Y-shaped tube with that of the utricle. From its posterior part a duct, the *ductus endolymphaticus*, is given off, and is joined by the ductus utriculosaccularis; the ductus endolymphaticus passes inwards and then downwards along the aquæductus vestibuli and ends in a blind pouch

FIG. 995.—The right membranous labyrinth of a fifth-month human embryo. × 10. Anterolateral aspect. (G. Retzius.)



(*saccus endolymphaticus*) under the dura mater on the posterior surface of the petrous portion of the temporal bone. From the lower part of the saccule a short tube, the *canalis reuniens* of Hensen, passes downwards and gradually widens into the vestibular or lower end of the ductus cochlearis (fig. 994).

The **semicircular ducts** (fig. 997) are about one-fourth of the diameter of the osseous semicircular canals, but are similar to them in shape and general form. Each has an ampulla at one end, viz.: the end which lies within the ampulla of the corresponding bony canal. The semicircular ducts open by five orifices into the utricle, one opening being common to the medial end of the superior and the upper end of the posterior duct. In each of the ampullæ the wall is thickened, and projects into the cavity as a transverse elevation shaped somewhat like the figure 8, and named the *septum transversum*; the most prominent part of this septum is termed the *crista ampullaris*.

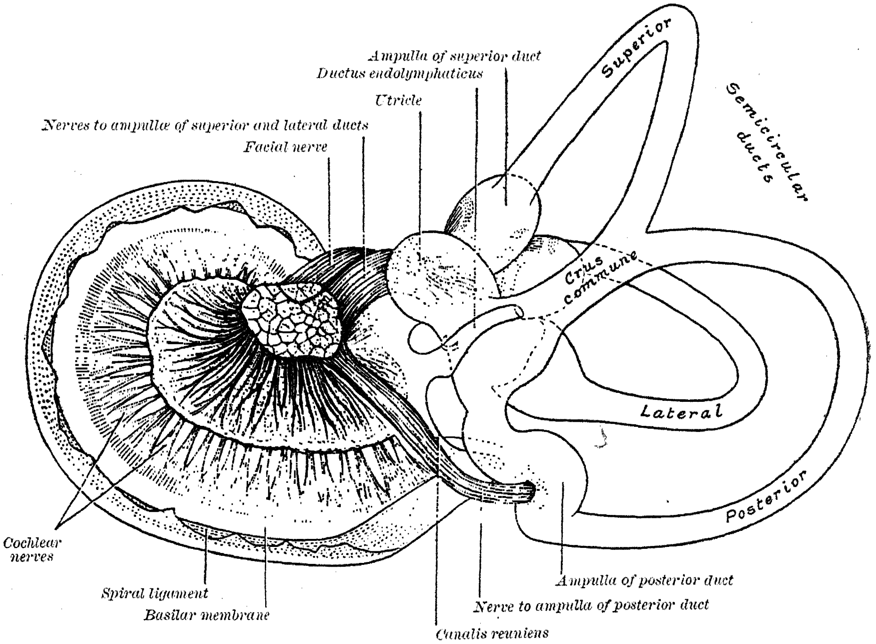
The utricle, saccule, and semicircular ducts are held in position by fibrous bands which stretch across the perilymphatic space to the bony walls.

Structure (fig. 997).—The walls of the utricle, saccule, and semicircular ducts consist of three layers. The *outer layer* is composed of ordinary fibrous tissue containing blood-vessels and some pigment-cells. The *middle layer*, thicker and more transparent, is named the *tunica propria*, and presents on its internal surface, especially in the semicircular ducts (fig. 997), numerous papilliform projections,

* Loc. cit.

which, on the addition of acetic acid, exhibit an appearance of longitudinal fibrillation. The *inner layer* is formed of polygonal nucleated epithelial cells. In the maculæ of the utricle and saccule (fig. 998), and in the cristæ ampullares of the semicircular ducts, the middle coat is thickened and the epithelium is columnar, and consists of *supporting cells* and *hair-cells*. The supporting cells are fusiform, and their deep ends are attached to the tunica propria, while their free extremities are united to form a thin cuticle. The hair-cells are flask-shaped, and their deep, rounded ends do not reach the tunica propria, but lie between the supporting cells. The deep part of each hair-cell contains a large nucleus, while its more superficial part is granular and pigmented. The free end of the cell is surmounted by a long, tapering, hair-like filament, which projects into the cavity. The filaments

FIG. 996.—The right membranous labyrinth of a fifth-month human embryo. × 10. Posteromedial aspect. (G. Retzius.)



of the vestibular nerve, having pierced the tunica propria, lose their medullary sheaths, and their axis-cylinders split up into fine fibrils which end between the hair-cells.

Two small rounded bodies termed *otoconia*, consisting of crystals of carbonate of lime, are suspended in the endolymph in contact with the free ends of the hairs projecting from the maculæ.

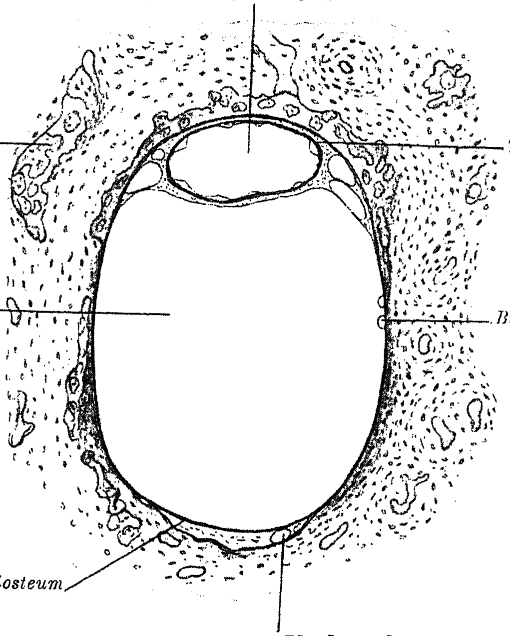
A ridge, named the *crista quarta*, projects into the posterior end of the lateral duct; nerves have been traced to this crista, which is present in most mammals, but exists only in a rudimentary condition in the higher vertebrates.

The **ductus cochlearis** or **scala media** consists of a spirally arranged tube enclosed in the bony canal of the cochlea and lying along its outer wall.

As already stated (p. 1038) the osseous spiral lamina extends only part of the distance between the modiolus and the outer wall of the cochlea, while the *basilar membrane* stretches from the free edge of the lamina to the outer wall of the cochlea, and completes the roof of the scala tympani. A second and more delicate membrane, the *vestibular membrane* (*Reissneri*) extends from the thickened periosteum covering the osseous spiral lamina to the outer wall of the cochlea, where it is attached at some distance above the outer edge of the basilar membrane. A canal is thus shut off between the scala tympani below and the scala vestibuli above; this is the *ductus cochlearis* or *scala media* (figs. 999, 1000). It is triangular on transverse section, its roof

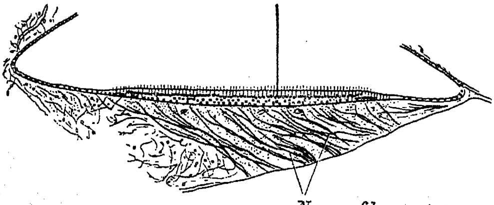
being formed by the vestibular membrane, its outer wall by the periosteum lining the bony canal, and its floor by the membrana basilaris and the outer part of the osseous spiral lamina. The upper extremity of the ductus cochlearis is closed, and is named the *lagœna*; it is attached to the cupula cochleæ. The

FIG. 997.—A transverse section through the right posterior semicircular canal and duct of an adult man. × 51. (J. K. Milne Dickie.)



lower end turns medialwards, and narrows into the *canalis reuniens* of Hensen, through which it communicates with the saccule (fig. 994). On the membrana basilaris is situated the spiral organ of Corti. The vestibular membrane is thin and homogeneous, and is covered on its upper and under surfaces by a layer of flattened epithelium. The periosteum forming the outer wall of the ductus cochlearis is greatly thickened and altered in character. It projects inwards inferiorly as a triangular prominence, the *crista basilaris*, to which the outer edge of the basilar membrane is fixed; immediately above this is a concavity, the *sulcus spiralis externus*, above which the periosteum contains numerous blood-vessels, and is termed the *stria vascularis*.

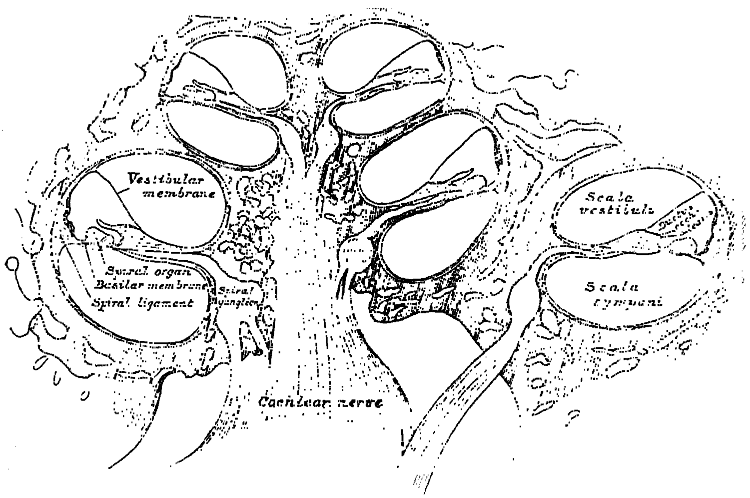
FIG. 998.—A transverse section of the macula acustica sacculi. (Retzius.)



The osseous spiral lamina consists of two plates of bone, and between these are the canals for the transmission of the filaments of the acoustic nerve. On the upper plate of that part of the lamina which is contained within the ductus cochlearis the periosteum is thickened to form the *limbus laminæ spiralis* (fig. 1001); this ends externally in a concavity, the *sulcus spiralis internus*, which presents, on section, the form of the letter C; the upper part formed by the overhanging edge of the limbus, is named the *vestibular lip*; the lower part, prolonged and tapering, is called the *tympanic lip*, and is

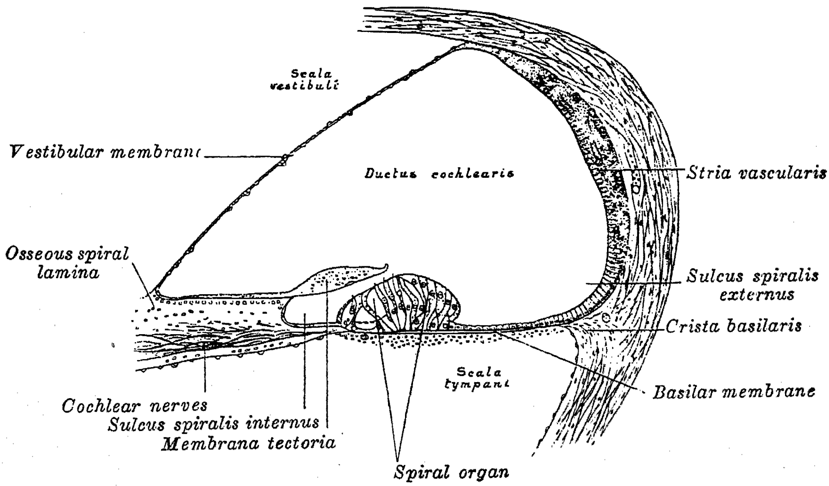
perforated by numerous foramina for the passage of the branches of the cochlear nerve. The upper surface of the vestibular lip is intersected at right angles by a number of furrows, between which are numerous elevations; these present the appearance of teeth on the free surface and margin of the lip, and

Fig. 999.—A longitudinal section through the cochlea. Diagrammatic.



were named by Huschke the *auditory teeth* (fig. 1001). The limbus is covered by a layer of what appears to be squamous epithelium, but only the cells covering the teeth are flattened, those in the furrows being columnar, and occupying the intervals between the elevations. This epithelium is continuous on the one hand with that lining the sulcus spiralis internus, and on the other with that covering the under surface of the vestibular membrane.

Fig. 1000.—A transverse section through the middle coil of the ductus cochlearis. (Retzius.)



The basilar membrane.—The basilar membrane stretches from the tympanic lip of the osseous spiral lamina to the crista basilaris. Its inner part is thin, and is named the *zona arcuata*; it supports the spiral organ of Corti; the outer part is thicker and striated, and is termed the *zona pectinata*.

7. The *layer of rods and cones.*—The elements composing this layer are of two kinds, *rods* and *cones*, the former being much more numerous than the latter except in the macula lutea. The *rods* are cylindrical, of nearly uniform thickness, and are arranged perpendicularly to the surface. Each rod consists of two segments, an outer and an inner, of about equal lengths. The segments differ from each other as regards refraction and in their behaviour towards colouring reagents; the inner segment is stained by carmine, iodine, &c.; the outer segment is not stained by these reagents, but is coloured yellowish-brown by osmic acid. The outer segment is marked by transverse striæ, and tends to break up into a number of thin superimposed discs; it also exhibits faint longitudinal markings. The inner part of the inner segment is indistinctly granular; the outer part is longitudinally striated, being composed of fine, highly refracting fibrils. The visual purple or rhodopsin is found only in the outer segments of the rods.

The *cones* are conical, their broad ends resting upon the membrana limitans externa, the pointed extremities being turned to the chorioid. Like the rods, each is made up of two segments, outer and inner; the outer segment is a short conical process, which, like the outer segment of a rod, exhibits transverse striæ. The inner segment resembles the inner segment of a rod in structure, presenting an outer striated and an inner granular part, but differs from it in size and shape, being flask-shaped. The optical characters of the two portions are identical with those of the rods.

Supporting framework of the retina.—The nervous layers of the retina are connected together by a supporting framework, formed by the *sustentacular fibres of Müller*; these fibres pass through all the nervous layers, except that of the rods and cones. Each fibre begins on the inner surface of the retina by an expanded, often forked, base, which sometimes contains a spheroidal body, staining deeply with hæmatoxylin; the edges of the bases of adjoining fibres are united to form the *membrana limitans interna*. As the sustentacular fibres pass through the stratum opticum and the ganglionic layer they send off a few lateral branches; in the inner nuclear layer they give off numerous lateral processes for the support of the bipolar cells, while in the outer nuclear layer they form a network and unite to form the *membrana limitans externa* at the bases of the rods and cones. At the level of the inner nuclear layer each sustentacular fibre contains a clear oval nucleus.

Structure of the macula lutea and fovea centralis.—At the fovea centralis there are no rods, and the cones are longer and thinner than in other parts of the retina. The nerve-fibre layer disappears at the margin of the fovea, and the other retinal layers are extremely thin. The pigment-cells are large and well-marked. At the circumference of the fovea the retina rapidly increases in thickness, so that this part of the macula lutea has a greater depth than any other part of the retina. All the layers are involved in this increase, but especially the ganglionic layer, in which the cells are six to eight deep. The yellow colour of the macula seems to imbue all the layers except that of the rods and cones; it is deepest towards the centre of the macula, and does not appear to be due to pigment-cells, but simply to a staining of the constituent parts.

At the *ora serrata* the nervous layers of the retina end abruptly, and the retina is continued onwards as a single layer of columnar cells along with the pigmented layer. This double layer is known as the *pars ciliaris retinæ*, and can be traced forwards from the ciliary processes on to the back of the iris, where it is termed the *pars iridica retinæ* or *uvea* (p. 1002).

The *arteria centralis retinæ* (fig. 958) and its accompanying vein pierce the lower and medial aspect of the optic nerve, and enter the bulb of the eye at the centre of the optic disc. The artery immediately bifurcates into an upper and a lower branch, and each of these again divides into a medial or nasal and a lateral or temporal branch, which at first run between the hyaloid membrane and the nervous layer; but they soon enter the latter, and pass forwards, dividing dichotomously. From these branches a minute capillary plexus is given off, which does not extend beyond the inner nuclear layer. The macula receives two small branches (superior and inferior macular arteries) from the temporal branches, and small twigs directly from the central artery; these do not, however, reach as far as the fovea centralis, which has no blood-vessels. The branches of the arteria centralis retinæ do not anastomose with each other—in other words, they are terminal arteries. In the fœtus, a small vessel, the arteria hyaloidea, passes forwards as a continuation of the arteria centralis retinæ through the vitreous humour to the posterior surface of the capsule of the lens.

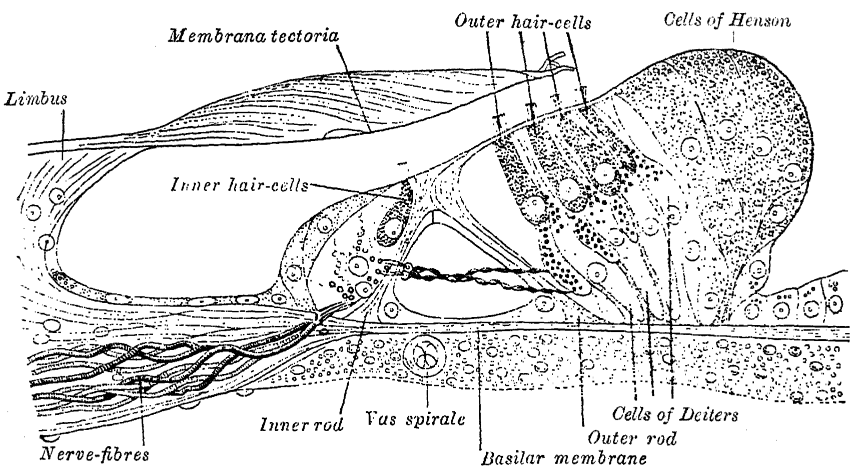
the outer rod. The head-plate, or portion overhanging the concavity, overlaps the head-plate of the outer rod.

The *outer rods*, nearly 4000 in number, are longer and more obliquely set than the inner, forming with the basilar membrane an angle of about 40°. Their heads are convex internally; they fit into the concavities on the heads of the inner rods, and are continued outwards as thin flattened plates, termed *phalangeal processes*, which unite with the phalangeal processes of Deiters' cells to form the reticular membrane.

The distances between the bases of the inner and outer rods increase from the base to the apex of the cochlea, while the angles between the rods and the basilar membrane diminish.

Hair-cells.—The hair-cells are short columnar cells; their free ends are on a level with the heads of Corti's rods, and each is surmounted by about

Fig. 1002.—A transverse section through the spiral organ of Corti. Magnified. (G. Retzius.)



twenty hair-like processes arranged in the form of a crescent with its concavity directed inwards. The deep ends of the cells reach about halfway along Corti's rods, and each contains a large nucleus; in contact with the deep ends of the hair-cells are the terminal filaments of the cochlear nerve. The *inner* hair-cells, about 3500 in number, are arranged in a single row on the medial (axial) side of the inner rods, and, their diameters being greater than those of the rods, each is supported by more than one rod. The free ends of the inner hair-cells are encircled by a cuticular membrane which is fixed to the heads of the inner rods. Adjoining the inner hair-cells are one or two rows of columnar supporting cells, which, in turn, are continuous with the cubical cells lining the sulcus spiralis internus. The *outer* hair-cells number about 12,000, and are nearly twice as long as the inner. In the basal coil of the cochlea they are arranged in three regular rows; in the apical coil, in four somewhat irregular rows.

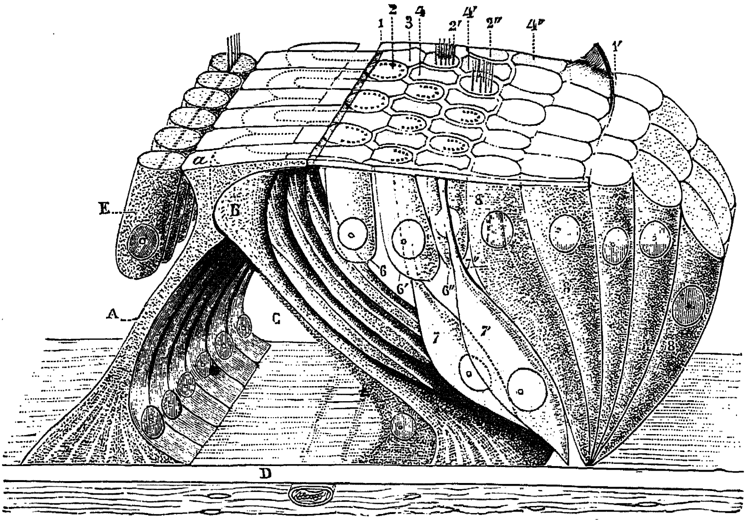
Between the rows of the outer hair-cells are rows of supporting cells, called the *cells of Deiters*; their expanded bases are planted on the basilar membrane, while the opposite end of each presents a clubbed extremity or *phalangeal process*. Immediately to the outer side of Deiters' cells are five or six rows of columnar cells, the *supporting cells of Hensen*. Their bases are narrow, while their upper parts are expanded and form a rounded elevation on the floor of the ductus cochlearis. The columnar cells lying outside Hensen's cells are termed the *cells of Claudius*. A space exists between the outer rods of Corti and the adjacent hair-cells; this is called the *space of Nuel*.

The *reticular lamina* (fig. 1003) is a delicate framework perforated by circular holes which are occupied by the free ends of the outer hair-cells. It extends

from the heads of the outer rods of Corti to the external row of the outer hair-cells, and is formed by several rows of minute fiddle-shaped cuticular structures, called *phalanges*, between which are circular apertures containing the free ends of the hair-cells. The innermost row of phalanges consists of the phalangeal processes of the outer rods of Corti; the outer rows are formed by the modified free ends of Deiters' cells.

The *tectorial membrane* overlies the sulcus spiralis internus and the spiral organ of Corti. It is wider and thicker in the apical than in the basal part of the cochlea. Its inner part is thin and is attached to the vestibular lip of the limbus laminæ spiralis, the attachment reaching as far as the vestibular membrane. The outer part is thick and padlike, the thickness being greatest over, or slightly to the inner side of, the upper ends of Corti's rods. Retzius

FIG. 1003.—The reticular lamina and subjacent structures. Schematic. (Testut.)



A. Inner rod of Corti, with *a*, its head. B. Outer rod (in yellow). C. Tunnel of Corti. D. Basilar membrane. E. Inner hair-cells. 1, 1′. Internal and external borders of the reticular lamina. 2, 2′, 2″. The three rows of circular holes (in blue). 3. First row of phalanges (in yellow). 4, 4′, 4″. Second, third, and fourth rows of phalanges (in red). 6, 6′, 6″. The three rows of outer hair-cells (in blue). 7, 7′, 7″. Cells of Deiters. 8. Cells of Hensen and Claudius.

described the outer edge as being attached to the outer row of Deiters' cells, while others maintain that it forms a ragged or frayed margin. Hardesty,* who has examined the membrane in the pig, states that this edge is free and bluntly rounded, but finely and irregularly scalloped. The hairs of the hair-cells project into the under surface of the membrane, and on this surface, opposite the interval between the inner and outer rows of hair-cells, is a band, named *Hensen's stripe*.

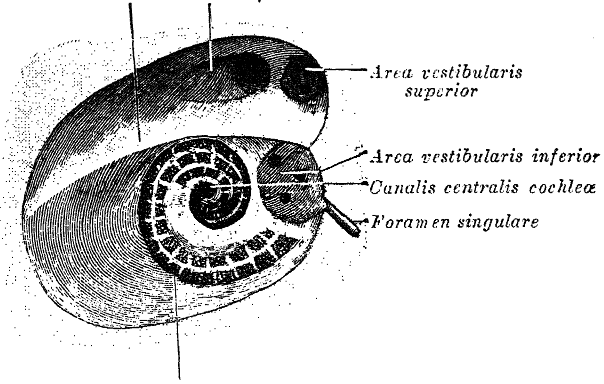
Hardesty has shown that the membrane "consists of multitudes of delicate fibrils embedded in a transparent matrix of a soft, collagenous, semi-solid character with marked adhesiveness." The prevailing course of the fibres is obliquely transverse, slanting from the vestibular lip towards the apex of the cochlea. The fibres pass in curves from the vestibular lip and upper surface of the membrane to its under surface, where by their interlacement they produce the appearance known as Hensen's stripe. He also describes a thin, exceedingly delicate *accessory tectorial membrane*, lying along the under surface of the outer zone of the main membrane, and lightly attached to the latter by its outer edge.

The **acoustic nerve**, or nerve of hearing, divides near the bottom of the internal acoustic meatus into an anterior or cochlear, and a posterior or vestibular portion. The deep connexions of these nerves are described on pp. 913 to 915.

* Irving Hardesty, *American Journal of Anatomy*, vol. viii.

The *vestibular nerve* supplies the utricle, the saccule, and the ampullæ of the semicircular ducts. On the trunk of the nerve, within the internal acoustic meatus, is the *vestibular ganglion* (ganglion of Scarpa), from the bipolar nerve-cells of which the fibres of the nerve take origin. On the distal side of the ganglion the nerve splits into a superior, an inferior, and a posterior branch.* The filaments of the *superior branch* are transmitted through the foramina in the

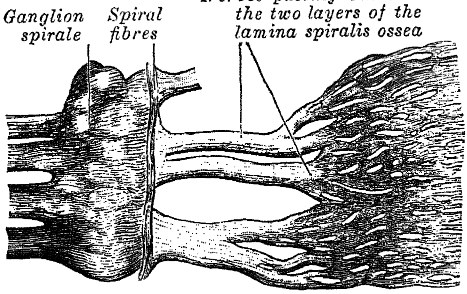
FIG. 1004.—A diagrammatic view of the lateral end of the right internal acoustic meatus. (Testut.)



area vestibularis superior, and end in the macula of the utricle and in the cristæ ampullares of the superior and lateral semicircular ducts; those of the *inferior branch* traverse the foramina in the area vestibularis inferior, and end in the macula of the saccule. The *posterior branch* runs through the foramen singulare at the postero-inferior part of the bottom of the meatus and divides into filaments for the supply of the crista ampullaris of the posterior semicircular duct (fig. 1004).

The *cochlear nerve*, the nerve of hearing, divides into numerous filaments at the base of the modiolus; those for the basal and middle coils pass through the foramina in the tractus spiralis foraminosus, those for the apical coil through the canalis centralis, and the nerves bend outwards and pass between the lamellæ of the osseous spiral lamina. Occupying the spiral canal of the modiolus is the *spiral ganglion of the cochlea* (ganglion of Corti) (fig. 1005), consisting of bipolar nerve-cells from which the fibres of the nerve take origin. Reaching the outer edge of the osseous spiral lamina, the nerve-fibres pass through the foramina in the tympanic lip; some end by arborising around the deep ends of the inner hair-cells, while others pass between Corti's rods and across Corti's tunnel, and end in a similar manner in relation to the outer hair-cells. The hair-cells in the basal and middle coils are more richly supplied with nerves than the hair-cells in the apical coil. The cochlear nerve gives off a vestibular branch to supply the vestibular end of the ductus cochlearis; the filaments of this branch traverse the foramina in the fossa cochlearis (p. 1036).

FIG. 1005.—Part of the cochlear division of the acoustic nerve. Highly magnified. (Henle.)



* The nerve sometimes splits on the proximal side of the ganglion, which is then divided into three parts, one on each branch of the nerve. When this occurs the ganglion of the posterior division is placed in the foramen singulare.

Vessels. The *arteries of the labyrinth* are the internal auditory branch of the basilar artery, and the stylomastoid branch of the posterior auricular artery. The internal auditory artery divides at the bottom of the internal acoustic meatus into two branches: cochlear and vestibular. The cochlear branch subdivides into twelve or fourteen twigs, which traverse the canals in the modiolus, and are distributed, in the form of a capillary network, in the lamina spiralis and basilar membrane. The vestibular branches are distributed to the utricle, saccule, and semicircular ducts.

The *veins* of the vestibule and semicircular canals accompany the arteries, and, receiving the veins of the cochlea at the base of the modiolus, unite to form the internal auditory veins which end in the posterior part of the superior petrosal sinus or in the transverse sinus. A small vein, from the basal turn of the cochlea, traverses the aquæductus cochleæ and joins the internal jugular vein.

Applied Anatomy.—The diseased conditions which may be found in the internal ear usually result from the spread of a suppurative process from the middle ear—thus in chronic suppuration of the latter, destruction of the internal ear may take place, with necrosis of parts of the cochlea or vestibule. Such cases will be associated with 'nerve-deafness,' and the disease may spread by means of the sheaths of the facial and acoustic nerves into the posterior fossa of the skull.

Hæmorrhage occasionally occurs into the labyrinth in certain blood disorders, resulting in complete 'nerve-deafness,' and such conditions may be associated with symptoms known as 'Menière's disease,' vertigo, giddiness, and tinnitus. Nerve-deafness is diagnosed when all 'bone-conduction' of sound is lost, and is most commonly seen in patients suffering from congenital syphilis, many deaf-mutes being the subjects of this condition. It is also not rare after mumps.

THE PERIPHERAL TERMINATIONS OF THE NERVES OF GENERAL SENSATIONS

The peripheral terminations of the nerves associated with general sensations (i.e. the muscular sense and the senses of heat, cold, pain, and pressure) are widely distributed throughout the body. These nerves may end (*a*) as *free fibrils* amongst the tissue elements, or (*b*) in *special end-organs* where the terminal nerve-filaments are enclosed in capsules.

Free nerve-endings occur chiefly in the epidermis and in the epithelium covering certain mucous membranes; they occur in the stratified squamous epithelium of the cornea, in the root-sheaths and papillæ of the hairs, and around the bodies of the sudoriferous glands.

When the nerve-fibre approaches its termination, the medullary sheath suddenly disappears, leaving the axis-cylinder surrounded by the neurolemma. After a time the fibre loses its neurolemma, and consists only of an axis-cylinder, which can be seen, in preparations stained with chloride of gold, to be made up of fine varicose fibrillæ. Finally, the axis-cylinder breaks up into its constituent fibrillæ, which often present regular varicosities, and anastomosing with one another, end in small knobs or discs between the epithelial cells.

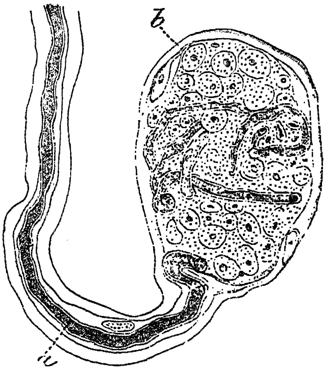
Peripheral pain end-organs consist of the free arborisations of naked axis-cylinders; end-organs other than those of pain are enveloped by capsules.

The **special end-organs** exhibit great variety in size and shape, but have one feature in common, viz. the terminal fibrils of the nerve are enveloped by a capsule. Included in this group are the end-bulbs of Krause; the corpuscles of Grandry, of Pacini, of Herbst, of Golgi and Mazzoni, of Wagner and Meissner; and the neurotendinous and neuromuscular spindles.

The *end-bulbs of Krause* (fig. 1006) are minute cylindrical or oval bodies, consisting of a capsule of connective tissue enveloping a soft semi-fluid core in which the axis-cylinder terminates either in a bulbous extremity or in a coiled-up plexiform mass. End-bulbs are found in the conjunctiva of the eye (where they are spheroidal in shape in man, but cylindrical in most other animals), in the mucous membrane of the lips and tongue, and in the epineurium of nerve-trunks. They are also found in the penis and clitoris, and have there received the name of *genital corpuscles*; in these situations they have a mulberry-like appearance, being constricted by connective tissue septa into from two to six knob-like masses. In the synovial strata of certain joints (e.g. those of the fingers), rounded or oval end-bulbs occur, and are designated *articular end-bulbs*.

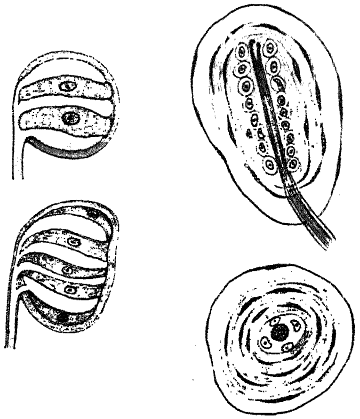
The *tactile corpuscles of Grandry* (fig. 1007*a*) occur in the papillæ of the beaks and tongues of ducks and geese. Each has a capsule composed of a delicate, nucleated membrane, within which are two or more granular, somewhat flattened cells between which the axis-cylinder ends in flattened discs.

FIG. 1006.—An end-bulb of Krause. (From Klein's Elements of Histology.)



a. Medullated nerve-fibre. *b*. Capsule.

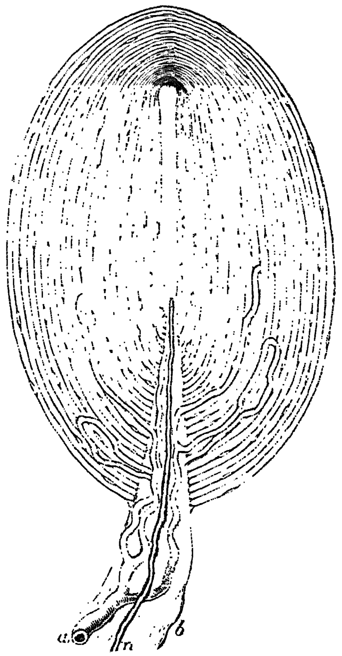
FIG. 1007.—Tactile corpuscles; (*a*) of Grandry, (*b*) of Herbst.



b

The *Pacinian corpuscles* (fig. 1008) are found in the subcutaneous tissue on the nerves of the palm of the hand and sole of the foot, and in the genital organs of both sexes; they also occur on the nerves of the joints, and in some other situations, as in the mesentery and pancreas of the cat and along the tibia of the rabbit. Each of these corpuscles is attached to and encloses the termination of a single nerve-fibre. The corpuscle (which is visible to the naked eye and can be most easily demonstrated in the mesentery of a cat) consists of a number of concentric lamellæ or capsules arranged around a central space, in which the nerve-fibre is contained. Each lamella is composed of bundles of fine connective tissue fibres, and is lined on its inner surface by a single layer of flattened cells. The central space is elongated or cylindrical in shape, and filled with a transparent core, in the middle of which the axis-cylinder traverses the space to near its distal extremity, where it ends in one or more small knobs. Todd and Bowman have described minute arteries as entering by the sides of the nerves and forming capillary loops in the intercapsular spaces, and even penetrating into the central space.

FIG. 1008.—A Pacinian corpuscle, with its system of capsules and its central cavity.



a. Arterial twig, ending in capillaries, which form loops in some of the intercapsular spaces; one penetrates to the central capsule. *b*. The fibrous tissue of the stalk. *n*. Nerve-fibre advancing to the central capsule, there losing its medullary sheath, and passing along the core to the opposite end, where it terminates in a tuberculated enlargement.

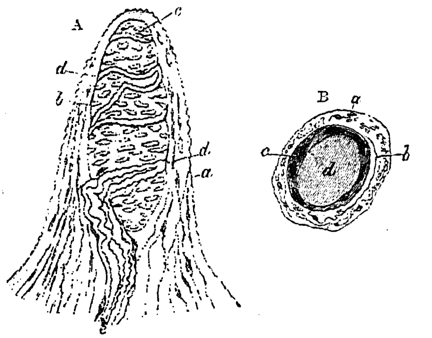
Herbst has described a nerve-ending somewhat similar to the Pacinian corpuscle, in the mucous membrane of the tongue of the duck, and in some other situations. It differs, however, from the Pacinian corpuscle in being smaller, in its capsules being more closely approximated, and especially in the fact that the axis-cylinder

in the central clear space is coated with a continuous row of nuclei. These nerve-endings are known as the *corpuscles of Herbst* (fig. 1007*b*).

The *corpuscles of Golgi and Mazzoni* are found in the subcutaneous tissue of the pulp of the fingers. They differ from Pacinian corpuscles in that their capsules are thinner, their contained cores thicker, and in the latter the axis-cylinders ramify more extensively and end in flat expansions.

The *tactile corpuscles of Wagner and Meissner* (fig. 1009) are oval-shaped bodies which occur in the papillæ of the corium of the hand and foot, the front of the forearm, the skin of the lips, the mucous membrane of the tip of the tongue, the palpebral conjunctiva, and the skin of the mammary papilla. Each is enveloped by a connective tissue capsule, which sends membranous septa into the interior. The axis-cylinder passes through the capsule, and after making several spiral turns round the body of the corpuscle ends in small globular or pear-shaped enlargements.

Fig. 1009.—A papilla of the hand, containing a tactile corpuscle of Wagner and Meissner. × 350.

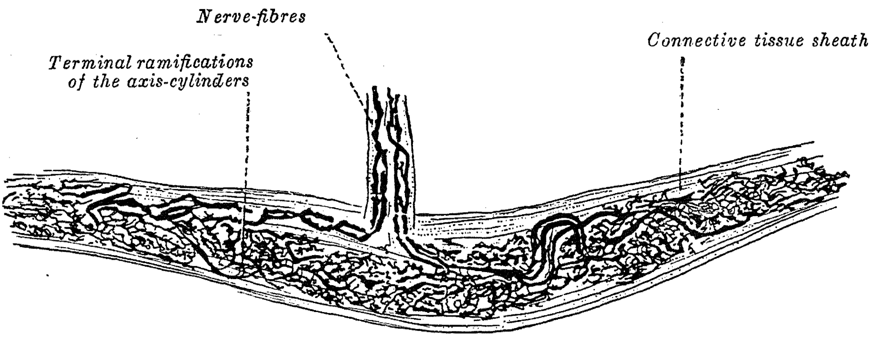


A. Side view of a papilla. *a.* Capsule. *b.* Tactile corpuscle. *c.* Small nerve of the papilla, with neurolemma. *d.* Its two nerve-fibres running with spiral coils round the tactile corpuscle *e.* Apparent termination of one of these fibres. B. Transverse section of a tactile papilla. *a.* Capsule. *b.* Nerve-fibre. *c.* Outer layer of the tactile corpuscle, with nuclei. *d.* Clear internal substance.

Corpuscles of Ruffini.—Ruffini described a special variety of nerve-ending in the subcutaneous tissue of the human finger (fig. 1010), and mostly situated at the junction of the corium with the subcutaneous tissue. They are oval in shape, and consist of strong connective tissue sheaths; inside these the nerve-fibres divide into numerous branches, which show varicosities and end in small free knobs.

The *neurotendinous spindles* or *organs of Golgi* are chiefly found near the junctions of tendons with muscles. Each is enclosed in a capsule which contains a number of enlarged tendon-fasciculi (*intrafusal fasciculi*). One or more nerve-fibres perforate the side of the capsule and lose their medullary sheaths; the

Fig. 1010.—A nerve-ending of Ruffini.

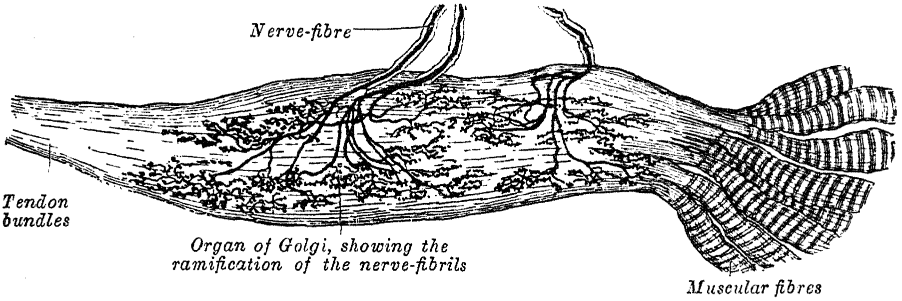


axis-cylinders subdivide and end between the tendon-fibres in irregular discs or varicosities (fig. 1011).

The *neuromuscular spindles* are present in the majority of voluntary muscles, and consist of small bundles of peculiar muscular fibres (*intrafusal fibres*), embryonic in type, invested by capsules, within which nerve-fibres, experimentally shown to be sensory, terminate. These neuromuscular spindles vary in length from 0·8 mm. to 5 mm. and have a fusiform appearance. The large medullated nerve-fibres passing to the end-organ are from one to three or four in number; entering the fibrous capsule, they divide several times, and, losing their medullary sheaths,

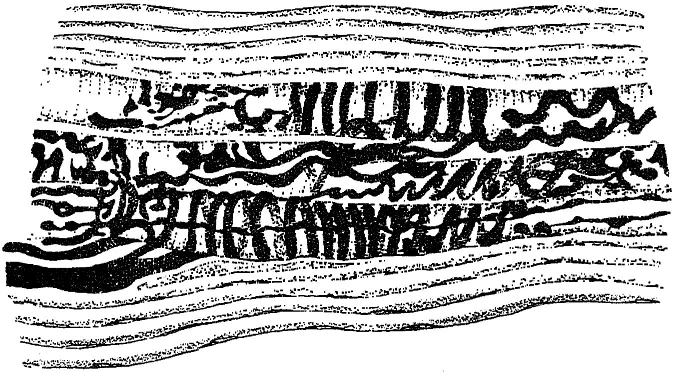
ultimately end in naked axis-cylinders encircling the intrafusal fibres by flattened expansions, or irregular ovoid or rounded discs (fig. 1012). Neuromuscular spindles

FIG. 1011.—A neurotendinous spindle or organ of Golgi from the human tendo calcaneus. (After Ciaccio.)



have not yet been demonstrated in the muscles of the tongue, and only a few exist in the ocular muscles.

FIG. 1012.—The middle third of a terminal plaque in the muscle-spindle of an adult cat. (After Ruffini.)



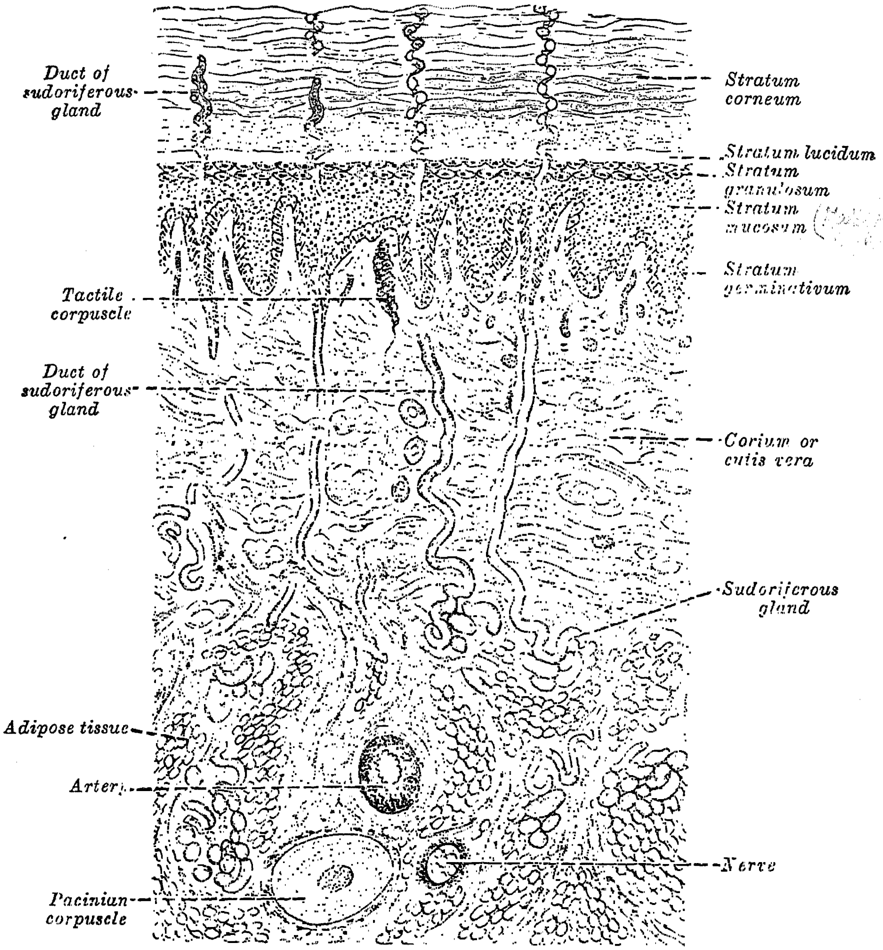
THE COMMON INTEGUMENT

The **integument** or **skin** (fig. 1013) covers the body and protects the deeper tissues. It contains the peripheral endings of many of the sensory nerves, plays an important part in the regulation of the body temperature, and possesses limited excretory and absorbing powers. It consists principally of a layer of vascular connective tissue, named the *corium* or *cutis vera*, and an external covering of epithelium, termed the *epidermis* or *cuticle*. On the surface of the former layer are sensitive and vascular *papillæ*; and within, or beneath it, are certain organs with special functions: namely, the *sudoriferous* and *sebaceous glands*, and the *hair-follicles*.

The **epidermis** or **cuticle** is non-vascular, and consists of stratified epithelium (fig. 1014). It varies in thickness in different parts. In some situations, as in the palms of the hands and soles of the feet, it is thick, hard, and horny in texture. This may be in a measure due to the fact that these parts are exposed to intermittent pressure, but that this is not the only cause is proved by the fact that the condition exists to a very considerable extent at birth. The more superficial layers of cells form the *horny layer* (*stratum corneum*), which may be separated by maceration from a deeper stratum, the *stratum mucosum*, consisting of several layers of differently shaped cells. The free surface of the epidermis is marked by a network of linear furrows of variable size, dividing the surface into a number of polygonal or lozenge-shaped areas. These furrows are large opposite the flexures of the joints, and

correspond with the folds in the corium produced by the joint-movements. In other situations, as upon the back of the hand, they are small, and intersect one another at various angles. Upon the palmar surfaces of the hands and fingers, and upon the soles of the feet, these lines are fine but very distinct, and are disposed in more or less parallel curves; they depend upon the large size and peculiar arrangement of the papillæ upon which the epidermis is placed. In each individual the lines on the tips of the fingers and thumbs form distinct patterns unlike those of any other person. A method of determining the identity of a criminal is based on this fact,

Fig. 1013.—A section through the skin. Magnified. Diagrammatic.



impressions ('finger-prints') of these lines being made on paper covered with soot, or on white paper after first covering the fingers with ink. The deep surface of the epidermis is accurately moulded upon the papillary layer of the corium, the papillæ being covered by a basement-membrane; so that when the epidermis is removed by maceration, its under surface presents a number of pits or depressions corresponding with the papillæ, and ridges corresponding with the intervals between them.

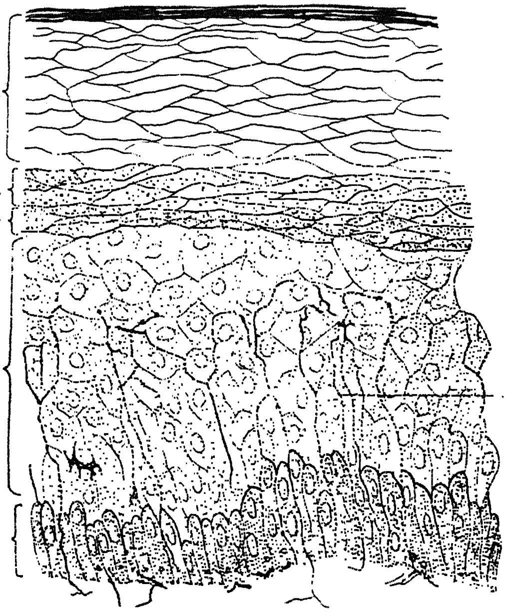
The epidermis consists of stratified epithelium which is arranged in five layers named from within outwards: (*a*) stratum germinativum, (*b*) stratum mucosum, (*c*) stratum granulosum, (*d*) stratum lucidum, and (*e*) stratum corneum.

The *stratum germinativum* consists of a layer of columnar cells with oblong nuclei. The cells are placed perpendicularly on the basement-membrane and attached to it by denticulated extremities.

The *stratum mucosum* is composed of several layers of spherical or polyhedral cells, the contents of which are soft, opaque, and granular. These cells are joined to one another by fine protoplasmic bridges. When the cells are isolated these bridges are broken and the surfaces of the cells are beset with numerous short thorn-like processes which give the cells a characteristic appearance and have led to their being named *prickle-cells*. The cells contain numerous fine fibrils which can be stained by carmine or hæmatoxylin, and are continuous with those of neighbouring cells across the protoplasmic bridges. Between the bridges are minute lymph-channels in which lymph-corpuscles or pigment-granules may be found.

The *stratum granulosum* comprises two or three layers of fusiform cells which contain granules of *eleidin*, a substance readily stained by hæmatoxylin or carmine, and probably an intermediate stage in the formation of keratin. They are supposed to be cells undergoing transformation from the protoplasmic cells of the stratum mucosum to the horny cells of the superficial layers.

FIG. 1014.—A section through the epidermis. (Ranvier.)



The *stratum lucidum* appears in section as a homogeneous or dimly striated layer, composed of closely packed cells in which traces of flattened nuclei may be found, and in which the eleidin has been changed into a substance named *keratohyalin*.

The *stratum corneum* consists of several layers of horny epithelial cells in which no nuclei are discernible. They are unaffected by acetic acid, and their protoplasm has been converted into a material, known as *keratin*. According to Ranvier they contain granules of a substance which has the characteristics of beeswax.

The black colour of the skin in the negro and the tawny colour in some of the white races are due to the presence of pigment in the cells of the epidermis. This pigment is especially distinct in the cells of the stratum mucosum, and is similar to that found in the cells of the pigmentary layer of the retina. As the cells approach the surface and desiccate, the pigment is partially lost.

The **corium or cutis vera** is tough, flexible, and highly elastic. It is very thick in the palms of the hands and soles of the feet; thicker on the posterior than on the anterior aspect of the body, and on the lateral than on the medial sides of the limbs. It is exceedingly thin and delicate in the eyelids, scrotum, and penis.

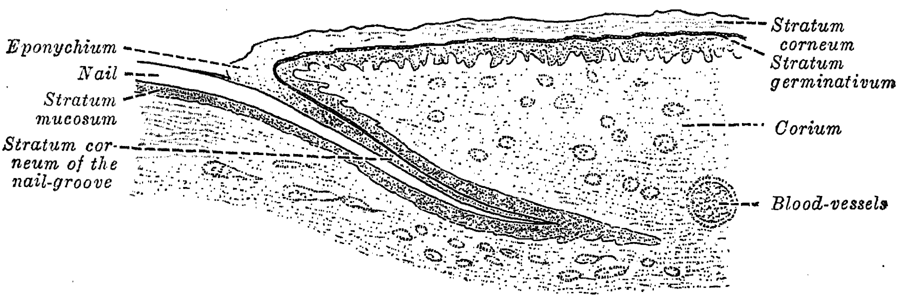
It consists of felted connective tissue, with a varying number of elastic fibres and numerous blood-vessels, lymphatic vessels, and nerves. The connective tissue is arranged in two layers: a deeper or *reticular*, and a superficial or *papillary*.

Unstriped muscular fibres are found in the superficial layers of the corium wherever hairs are present; they are also present in the subcutaneous areolar tissue of the scrotum, penis, labia majora, and nipples. In the nipples the fibres are disposed in bands, closely reticulated and arranged in superimposed laminæ.

The *reticular layer* consists of strong interlacing bands, composed chiefly of white fibrous tissue, but containing some yellow elastic fibres which vary in number in different parts; the connective tissue corpuscles are often to be found flattened against the bundles of white fibrous tissue. Towards the attached surface the fasciculi are coarse, and the large areolæ left by their interlacement are occupied by adipose tissue and sweat-glands. Below the reticular layer is the subcutaneous areolar tissue, which, except in a few situations, contains fat.

The *papillary layer* consists of numerous highly sensitive and vascular eminences, the *papillæ*, which rise perpendicularly from its surface. The papillæ are minute conical projections, having round or blunted extremities, which may be divided into two or more parts, and are received into corresponding pits on the under surface of the cuticle. On the general surface of the body, and especially in parts endowed with slight sensibility, they are few in number, and exceedingly minute; but in some situations, as upon the palmar surfaces of the hands and fingers, and upon the plantar surfaces of the feet and toes, they are large, closely aggregated together,

Fig. 1015.—A longitudinal section through the root of a nail.



and arranged in parallel curved lines, forming the elevated ridges seen on the free surface of the epidermis. Each ridge contains two rows of papillæ, and between the rows the ducts of the sudoriferous glands pass outwards to open on the summits of the ridges. Each papilla consists of very small and closely interlacing bundles of finely fibrillated tissue, with a few elastic fibres; within this tissue is a capillary loop, and in some papillæ, especially in the palms of the hands and the fingers, there are tactile corpuscles.

The *arteries* supplying the skin form a network in the subcutaneous tissue, and from this network branches are distributed to the sudoriferous glands, the hair-follicles, and the fat. Other branches unite in a plexus immediately beneath the corium, and from this plexus fine capillary vessels pass into the papillæ.

The *lymphatic vessels* of the skin form a superficial and a deep network, which communicate with each other and with the lymphatic vessels of the subcutaneous tissue by oblique branches.

The *nerves* of the skin terminate partly in the epidermis and partly in the corium; their different modes of ending are described on pp. 1048 to 1050.

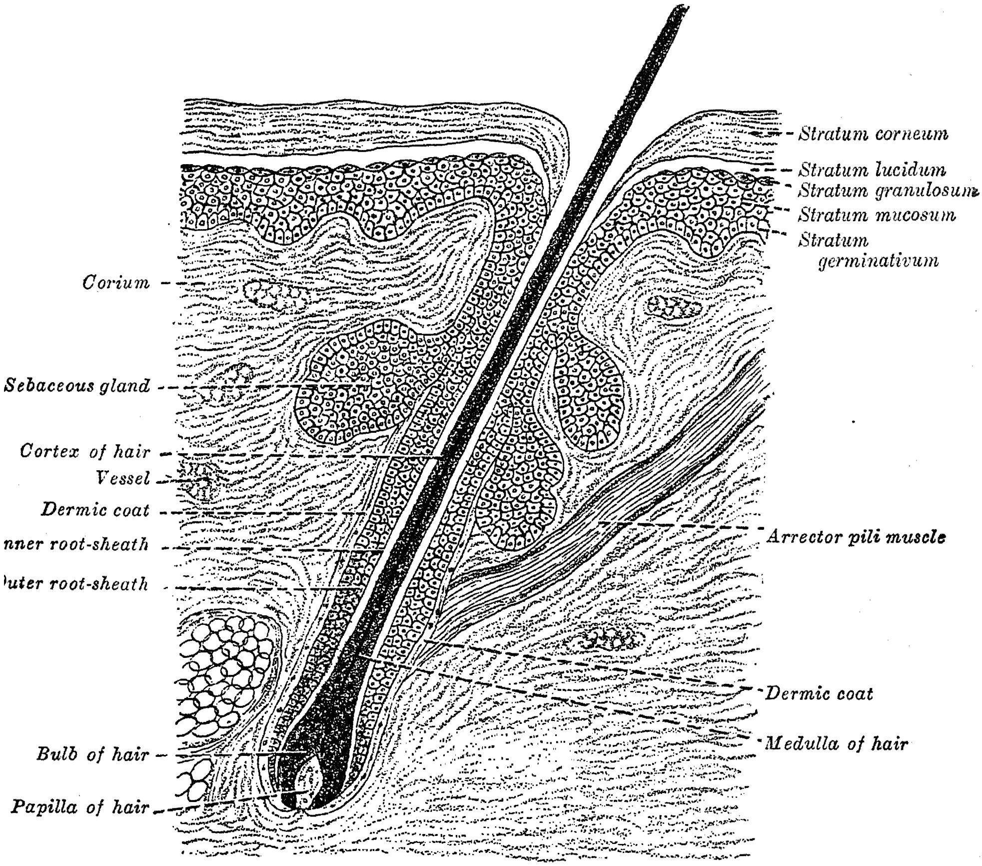
The **appendages of the skin** are the nails, the hairs, and the sudoriferous and sebaceous glands.

The **nails** (fig. 1015) are flattened, elastic structures of a horny texture, placed upon the distal parts of the dorsal surfaces of the fingers and toes. Each is implanted into a groove in the skin by a portion called the *root*; the exposed part is called the *body*, and the distal extremity the *free edge*. The nail is firmly adherent to the corium, being accurately moulded upon its surface; the part of the corium beneath the body and root of the nail is called the *nail-matrix*, because the nail is produced from it. Under the greater part of the body of the nail the matrix is thick, and raised into a series of longitudinal ridges which are very vascular, and the colour is seen through the transparent tissue. Near the root of the nail the papillæ are smaller, less vascular, and have no regular arrangement, and here

the tissue of the nail is more opaque ; hence this portion is of a white colour, and is called the *lunula* on account of its shape.

As the cuticle passes forwards on the dorsal surface of the finger or toe it is attached to the surface of the nail a little in advance of its root ; at the extremity of the finger it is connected with the under surface of the nail a little behind its free edge. The cuticle and the horny substance of the nail (both epidermic structures) are thus directly continuous with each other. The superficial, horny part of the

Fig. 1016.—A section through the skin, showing the epidermis and corium, a hair in its follicle, the Arrector pili muscle, with sebaceous glands opening into the hair-follicle.



nail consists of a greatly thickened stratum lucidum, the stratum corneum forming merely the thin cuticular fold (*eponychium*) which overlaps the lunula ; the deeper part consists of the stratum mucosum. The cells in contact with the papillæ of the nail-matrix are columnar in form and arranged perpendicularly to the surface ; the succeeding cells are round or polygonal, while the more superficial ones are thin and flat, and so closely packed as to make the limits of the cells very indistinct. The nails grow in length by the proliferation of the cells of the stratum mucosum at the root of the nail, and in thickness from that part of the stratum mucosum which underlies the lunula.

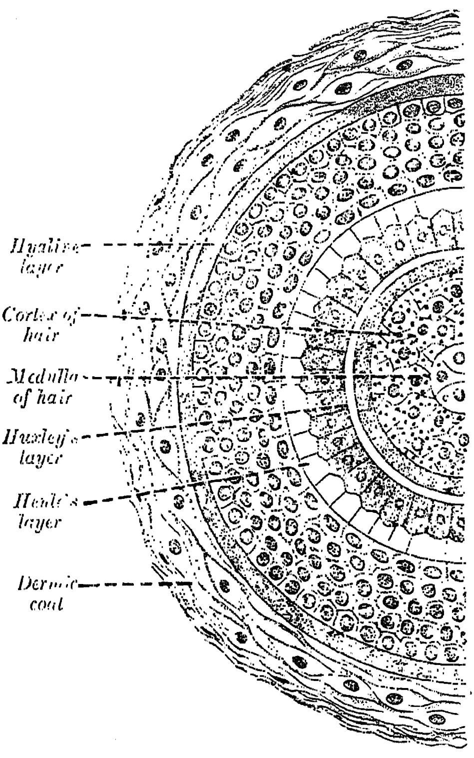
The **hairs** are found on nearly every part of the surface of the body, but are absent from the palms of the hands, the soles of the feet, the dorsal surfaces of the terminal phalanges, the glans penis, the inner surface of the prepuce, and the inner surfaces of the labia. They vary much in length, thickness, and colour in different parts of the body and in different races of mankind. In some parts, as in the skin of the eyelids, they are so short as not to project beyond the follicles containing them ; in others, as upon the scalp, they are of considerable length ; the eyelashes,

the hairs of the pubic region, and the whiskers and beard are remarkable for their thickness. Straight hairs are stronger than curly hairs and present on transverse section a cylindrical or oval outline: curly hairs, on the other hand, are flat.

A hair consists of a *root*, the part implanted in the skin; and a *shaft* or *scapus*, the portion projecting from the surface.

The *root of the hair* ends in an enlargement, the *hair-bulb*, which is whiter in colour and softer in texture than the shaft, and is lodged in an involution of the epidermis and superficial portion of the corium, called the *hair-follicle* (fig. 1016). When the hair is of considerable length the follicle extends into the subcutaneous tissue. The hair-follicle commences on the surface of the skin with a funnel-shaped opening, and passes inwards in an oblique or curved direction—the latter in curly hairs—to become dilated at its deep extremity, where it corresponds with the hair-bulb. Opening into the follicle, near its free extremity, are the ducts of one or more sebaceous glands. At the bottom of each hair-follicle is a small conical, vascular eminence or papilla, similar in every respect to those found upon the surface of the skin; it is continuous with the dermic layer of the follicle, and is supplied with nerve-fibrils. The hair-follicle consists of two coats—an outer or dermic, and an inner or epidermic.

FIG. 1017.—A transverse section through a hair-follicle.



The *outer or dermic coat* is formed mainly of fibrous tissue; it is continuous with the corium, is highly vascular, and supplied by numerous minute nervous filaments. It consists of three layers (fig. 1017). The most internal is a hyaline basement-membrane, which is well marked in the larger hair-follicles, but is not very distinct in the follicles of minute hairs; it is limited to the deeper part of the follicle. Outside this is a compact layer of fibres and spindle-shaped cells arranged circularly around the follicle; this layer extends from the bottom of the follicle to the openings of the ducts of the sebaceous glands. Externally is a thick layer of connective tissue, arranged in longitudinal bundles, forming a more open texture and corresponding with the reticular part of the corium; in this are contained the blood-vessels and nerves.

The *inner or epidermic coat* is closely adherent to the root of the hair, and consists of two strata named respectively the *outer* and *inner root-sheaths*; the outer root-sheath corresponds with the stratum mucosum of the epidermis, and resembles it in the rounded form and soft character of its cells; at the bottom of the hair-follicle these cells become continuous with those of the root of the hair. The inner root-sheath consists of: (1) a delicate cuticle next the hair, composed of a single layer of imbricated scales with atrophied nuclei; (2) one or two layers of horny, flattened, nucleated cells, known as *Huxley's layer*; and (3) a single layer of cubical cells with clear flattened nuclei, called *Henle's layer*.

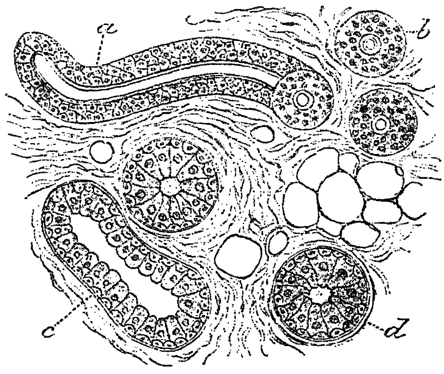
The *hair-bulb* is moulded over the papilla and composed of polyhedral epithelial cells, which as they pass upwards into the root of the hair become elongated and spindle-shaped, except those in the centre, which remain polyhedral.

The *shaft of the hair* consists, from within outwards, of the medulla, the cortex, and the cuticle. The *medulla* is usually absent from the fine hairs covering the

surface of the body, and commonly from those of the head. When viewed by transmitted light it appears deeper in colour and more opaque than the cortex, but when viewed by reflected light it is white. It is composed of rows of polyhedral cells, with air-spaces between, and sometimes within, the cells. The *cortex* constitutes the chief part of the shaft; its cells are elongated and are united to form flattened fusiform fibres which contain pigment-granules in dark hair, and air in white hair. The *cuticle* consists of a single layer of flat scales which overlap one another from below upwards.

Connected with the hair-follicles are minute bundles of involuntary muscular fibres, termed the *Arrectores pilorum* (fig. 1016). They arise from the superficial layer of the corium, and are inserted into the hair-follicle, below the entrance of the duct of the sebaceous gland. They are placed on the side towards which the hair slopes, and by their action diminish the obliquity of the follicle and elevate the hair.* The sebaceous gland is situated in the angle which the Arrector muscle forms with the superficial portion of the hair-follicle, and contraction of the muscle thus tends to squeeze the sebaceous secretion out from the duct of the gland.

Fig. 1018.—The body of a sudoriferous gland cut in various directions. (From Klein and Noble Smith's Atlas of Histology.)



a. Longitudinal section through the proximal part of the coiled tube. *b.* Transverse section through the same. *c.* Longitudinal section through the distal part of the coiled tube. *d.* Transverse section through the same.

The **sebaceous glands** (fig. 1016) are small, sacculated, glandular organs, lodged in the substance of the corium. They are found in most parts of the skin, but are especially abundant in the scalp and face; they are also very numerous around the apertures of the anus, nose, mouth, and external ear, but are wanting in the palms of the hands and soles of the feet. Each gland consists of a single duct, more or less capacious, which emerges from a cluster of oval or flask-shaped alveoli, usually from two to five, but in some instances as many as twenty in number. Each alveolus is composed of a transparent basement-membrane, enclosing a number of epithelial cells. The outer or marginal cells are small and polyhedral, and are continuous with the cells lining the duct. The remainder of the alveolus is filled with larger cells, containing fat, except in the centre, where the cells are broken up, leaving a cavity filled with their debris and a mass of fatty matter, which constitutes the *sebum cutaneum*. The ducts open most frequently into the hair-follicles, but occasionally upon the general surface, as in the labia minora and the free margins of the lips. On the nose and face the glands are of large size, distinctly lobulated, and often become much enlarged from the accumulation of pent-up secretion. The tarsal glands of the eyelids are elongated sebaceous glands with numerous lateral diverticula.

The **sudoriferous or sweat glands** (figs. 1013, 1018) are found in almost every part of the skin, and are situated in small pits on the under surface of the corium, or, more frequently, in the subcutaneous tissue, surrounded by a quantity of adipose tissue. Each consists of a single tube, the deep part of which is rolled into an oval or spherical ball, named the *body* of the gland, while the superficial part, or *duct*, traverses the corium and cuticle and opens on the surface of the skin by a funnel-shaped aperture. In the superficial layers of the corium the duct is straight, but in the deeper layers it is convoluted or twisted; where the epidermis is thick, as in the palms of the hands and soles of the feet, the part of the duct which passes through it is spirally coiled. The size of the glands varies. They are especially large in those regions where the amount of perspiration is great, as in the axillæ, where

* Professor A. Thomson of Oxford suggests that the contraction of these muscles on follicles which contain weak, flat hairs will tend to produce a permanent curve in the follicle, and this curve will be impressed on the hair which is moulded within it so that the hair, on emerging through the skin, will be curled. Curved hair-follicles are characteristic of the scalp of the Bushman.

they form a thin, mamillated layer of a reddish colour, which corresponds exactly with the situation of the hair in this region; they are large also in the groin. Their number varies. They are very plentiful on the palms of the hands, and on the soles of the feet, where the orifices of the ducts are exceedingly regular, and open on the curved ridges of the epidermis; they are least numerous in the neck and back. The tube, both in the body of the gland and in the duct, consists of two layers—an outer, of fine areolar tissue, and an inner of epithelium (fig. 1018). The outer layer is thin and is continuous with the superficial stratum of the corium. In the body of the gland the epithelium consists of a single layer of cubical cells, between the deep ends of which and the basement-membrane is a layer of longitudinally or obliquely arranged non-striped muscular fibres. The ducts are destitute of muscular fibres and are composed of a basement-membrane lined by two or three layers of polyhedral cells; the lumen of the duct is coated by a thin cuticle. When the epidermis is carefully removed from the surface of the corium, the ducts may be drawn out in the form of short, thread-like processes on its under surface.

The ceruminous glands of the external acoustic meatus are modified sudoriferous glands.

SPLANCHNOLOGY

UNDER this heading are described the respiratory, digestive, and urogenital organs, and the ductless glands.

THE RESPIRATORY ORGANS

The respiratory organs consist of the nose, pharynx, larynx, trachea, bronchi, lungs, and pleuræ. The nose is described on pp. 984 to 991, and the pharynx on pp. 1122 to 1127.

The Larynx

The **larynx**, the organ of the voice, is situated between the root of the tongue and the trachea, at the upper and anterior part of the neck, where it projects forwards between the great vessels, and is covered anteriorly by the skin, the fasciæ, and the depressor muscles of the hyoid bone (fig. 1019). Above, it opens into the laryngeal part of the pharynx, of which it forms the anterior wall; below, it is continuous with the trachea. In the adult male it is situated opposite the third, fourth, fifth, and sixth cervical vertebræ, but is placed somewhat higher in the female and also during childhood. Symington states that in infants of between six and twelve months of age the tip of the epiglottis, or highest part of the larynx, is a little above the level of the fibrocartilage between the dens and body of the epistropheus. Its average measurements in the adult are as follows:

	In males.	In females.
Length	44 mm.	36 mm.
Transverse diameter	43 ,,	41 ,,
Anteroposterior diameter	36 ,,	26 ,,
Circumference	136 ,,	112 ,,

Until puberty the larynx of the male differs little in size from that of the female. In the female its increase at puberty is only small. In the male it is considerable; all the cartilages enlarge and the thyreoid cartilage projects in the middle line of the neck, while the length of the rima glottidis is nearly doubled.

The upper part of the larynx is prismoid in form, flattened behind and at the sides, and forming in front a prominent vertical ridge (fig. 1019); its lower part is narrow and cylindrical (fig. 1020). It is composed of cartilages, which are connected by ligaments and membranes, and are moved by numerous muscles. It is lined with mucous membrane continuous above and behind with that of the pharynx and below with that of the trachea.

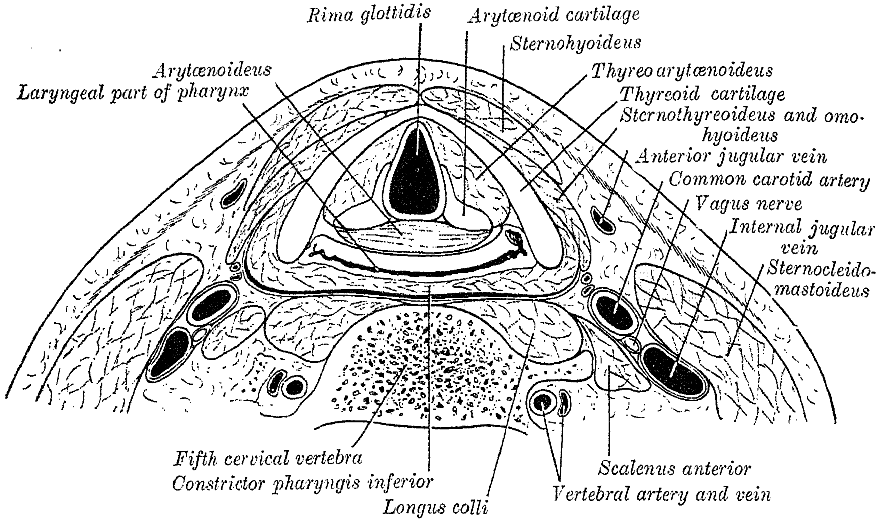
The **cartilages of the larynx** (fig. 1021) are nine in number, three single and three paired, as follows:

Thyreoid.	Two Corniculate.
Cricoid.	Two Cuneiform.
Two Arytænoid.	Epiglottis.

The **thyreoid cartilage** (figs. 1019, 1021, 1022, 1023) is the largest cartilage of the larynx. It consists of two laminæ, the anterior borders of which are

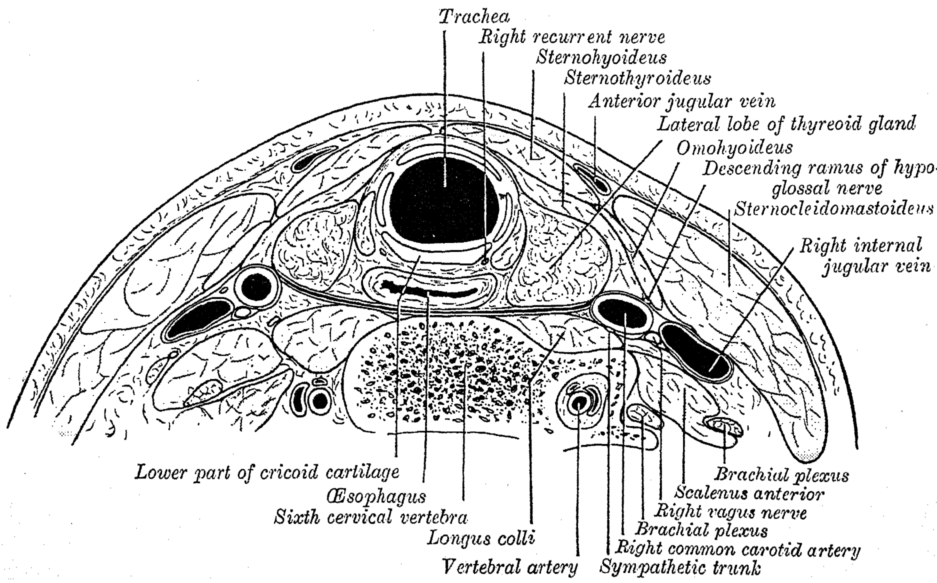
fused at an angle in the middle line of the neck, and form a subcutaneous projection named the *laryngeal prominence* (pomum Adami). This prominence is

FIG. 1019.—A section across the anterior part of the neck at the level of the vocal folds.



most distinct at its upper part, and is larger in the male than in the female. Immediately above it the laminæ are separated by a V-shaped notch, the *superior thyreoid notch.*

FIG. 1020.—A section across the anterior part of the neck at the level of the lower part of the lamina of the cricoid cartilage.



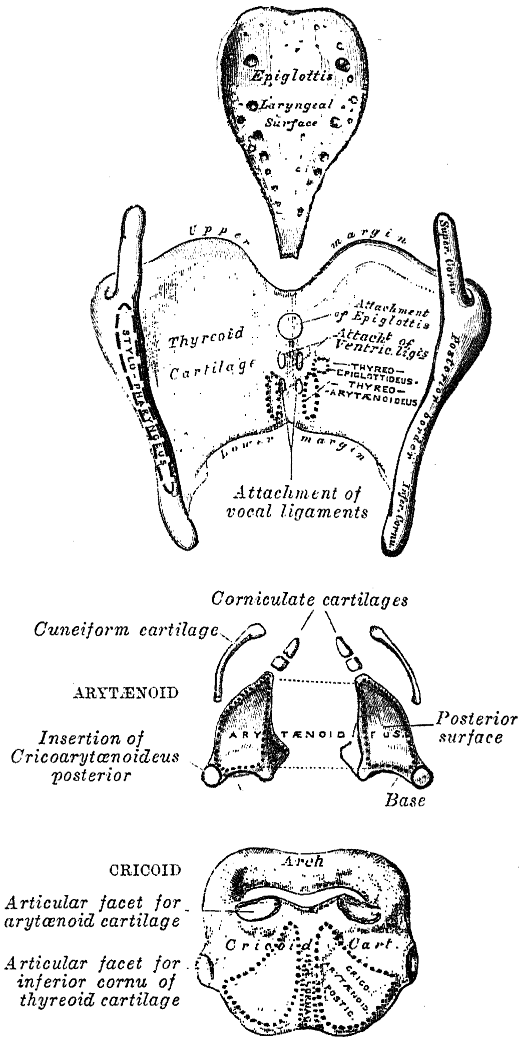
The *laminæ* are irregularly quadrilateral in shape, and their posterior angles are prolonged into processes termed the *superior* and *inferior cornua.*

On the *outer surface* of each lamina an *oblique line* runs downwards and forwards from the superior thyreoid tubercle which is situated a little in front of the root of the superior cornu, to the inferior thyreoid tubercle on the lower border of the lamina. To this line are attached the Sternothyreoideus, Thyreohyoideus, and Constrictor pharyngis inferior. The *inner surface* is smooth: above and behind, it is slightly concave and covered with mucous membrane. In front, in the angle formed by the junction of the laminæ, are attached the thyreo-epiglottic, ventricular, and vocal ligaments, the Thyreoarytænoidei, Thyreoepiglottici and Vocales muscles.

The *upper border* of each lamina is concave behind and convex in front; it gives attachment to the corresponding half of the hyothyreoid membrane. The *lower border* is concave behind, and nearly straight in front, the two parts being separated by the inferior thyreoid tubercle. A small part of it in and near the middle line is connected to the cricoid cartilage by the middle cricothyreoid ligament.

The *anterior* border is fused with that of the opposite lamina, forming with it an angle of about 90° in the male, and about 120° in the female. The *posterior border*, thick and rounded, receives the insertions of fibres of the Stylopharyngeus and Pharyngopalatinus muscles. It ends in the superior and inferior cornua. The *superior cornu*, long and narrow, is directed upwards, backwards and medialwards, and ends in a conical extremity, which gives attachment to the lateral hyothyreoid ligament. The *inferior cornu*, short and thick, is directed downwards, with a slight inclination forwards and medialwards; on the medial surface of its lower end there is a small oval facet for articulation with the side of the cricoid cartilage.

Fig. 1021.—The cartilages of the larynx. Posterior aspect.



During infancy the laminæ of the thyreoid cartilage are joined to each other by a narrow, lozenge-shaped, flexible strip, named the *intrathyreoid cartilage*.

The **cricoid cartilage** (figs. 1021, 1023, 1024) is smaller, but thicker and stronger than the thyreoid cartilage. It is shaped like a signet-ring, and forms the lower and posterior parts of the wall of the larynx. It consists of a posterior quadrate lamina, and an anterior narrow arch.

The *lamina* of the cricoid cartilage is deep and broad, and measures vertically from 2 cm. to 3 cm.; on the middle of its posterior surface is a vertical ridge to the upper part of which the two fasciculi of the longitudinal fibres of the œsophagus are attached by a tendon (p. 1129); and on either side of the ridge is a shallow depression for the origin of the Cricoarytænoideus posterior.

The *arch* is narrow in front, measuring vertically from 5 mm. to 7 mm., but widens posteriorly as it approaches the lamina; it affords attachment in front and at the sides to the Cricothyreoidei, and behind, to part of the Constrictor pharyngis inferior. On either side, at the junction of the lamina with the arch, there is a prominent circular facet, directed lateralwards and backwards, for articulation with the inferior cornu of the thyreoid cartilage. The *lower border* of the cricoid cartilage is horizontal, and connected to the highest ring of the trachea by the cricotracheal ligament. The *upper border* runs obliquely upwards and backwards, owing to the great depth of the lamina. It gives attachment, in front, to the middle cricothyreoid ligament; at the sides, to the conus elasticus and the Cricoarytænoidei laterales; behind, it presents, in the middle, a shallow notch, and on either side of this is a smooth, oval, convex surface, directed upwards and lateralwards, for articulation with the base of an arytænoid cartilage. The *inner surface* of the cricoid cartilage is lined with mucous membrane.

The **arytænoid cartilages** (figs. 1023, 1024), a right and a left, are situated at the upper border of the lamina of the cricoid cartilage, at the back of the larynx. Each is pyramidal in form, and has three surfaces, a base, and an apex.

The *posterior surface*, triangular, smooth, and concave, is covered with the Arytænoideus transversus. The *anterolateral surface* is somewhat convex and rough. On it, near the apex of the cartilage, there is an elevation (*colliculus*) from which a crest (*crista arcuata*) curves at first backwards and then downwards and forwards to the vocal process. The lower part of this crest intervenes between two depressions or foveæ, an upper, triangular, and a lower, oblong in shape; to the upper the ventricular ligament is attached; to the lower, the Vocalis and Cricoarytænoideus lateralis. The *medial surface* is narrow, smooth, and flat; it is covered with mucous membrane, and its lower edge forms the lateral boundary of the intercartilaginous part of the rima glottidis. The *base* is concave, and on it is a smooth surface for articulation with the upper border of the lamina of the cricoid cartilage. Its lateral angle or *muscular process*, rounded and prominent, projects backwards and lateralwards, and gives insertion to the Cricoarytænoideus posterior behind, and to the Cricoarytænoideus lateralis in front. Its anterior angle or *vocal process* is pointed; it projects horizontally forwards and gives attachment to the vocal ligament. The *apex* curves backwards and medialwards, and articulates with the *corniculate cartilage*.

The **corniculate cartilages** (cartilages of Santorini) (fig. 1024) are two small conical nodules of yellow elastic cartilage, which articulate with the summits of the arytænoid cartilages and serve to prolong them backwards and medialwards. They are situated in the posterior parts of the aryepiglottic folds of mucous membrane, and are sometimes fused with the arytænoid cartilages.

The **cuneiform cartilages** (cartilages of Wrisberg) (figs. 1021, 1024, 1025) are two small, elongated pieces of yellow elastic cartilage, placed one in each aryepiglottic fold, where they give rise to whitish elevations on the surface of the mucous membrane, just in front of the corniculate cartilages.

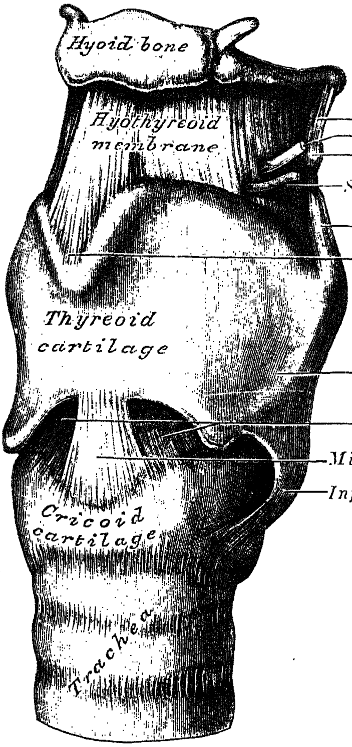
The cartilage of the **epiglottis** (figs. 1021, 1023, 1024) is a thin leaf-like lamella of yellow fibrocartilage, which projects obliquely upwards behind the tongue and the body of the hyoid bone, and in front of the entrance to the larynx. The free extremity, broad and rounded, is directed upwards; the attached part or stem is long, narrow, and connected by an elastic ligament, the *thyreo-epiglottic ligament*, to the angle formed by the two laminæ of the thyreoid cartilage, a short distance below the superior thyreoid notch. The sides of the epiglottis are attached to the arytænoid cartilages by the aryepiglottic folds of mucous membrane (p. 1066).

The upper part of the *anterior surface* of the epiglottis is free, and covered with mucous membrane, which is reflected on to the back of the tongue, forming a median and two lateral *glosso-epiglottic folds*; the lateral glosso-epiglottic folds are also attached to the wall of the pharynx, and on this account are frequently named the *pharyngo-epiglottic folds*. The depression on either side of the median glosso-epiglottic fold is named the *vallecula* (fig. 1026). The lower part of the anterior surface lies behind the hyoid bone and the hyothyreoid

membrane, and is connected to the upper border of the hyoid bone by an elastic ligament, the *hyo-epiglottic ligament*; it is separated from the hyothyreoid membrane by a mass of fatty tissue.

The *posterior surface* of the epiglottis is smooth, concave from side to side, concavoconvex from above downwards, and covered with mucous membrane; its lower part projects backwards as an elevation, the *tubercle* or *cushion*. When the mucous membrane is removed, the cartilage is seen to be indented by a number of small pits, in which mucous glands are lodged.

Fig. 1022.—The ligaments of the larynx. Anterolateral aspect.



Structure.—The corniculate and cuneiform cartilages, the epiglottis, and the apices of the arytænoids consist of yellow fibrocartilage, which shows little tendency to calcification. The thyreoid, cricoid, and the greater part of the arytænoids consist of hyaline cartilage, and become more or less ossified as age advances. Ossification commences about the twenty-fifth year in the thyreoid cartilage, and somewhat later in the cricoid and the arytænoids; by the sixty-fifth year these cartilages may be completely converted into bone.

Joints.—The joints between the inferior cornua of the thyreoid cartilage and the sides of the cricoid cartilage are diarthrodial, and each is enveloped by an articular capsule, which is strengthened posteriorly by a fibrous band. Rotatory and gliding movements occur at these joints. The rotatory movement is one in which the cricoid cartilage rotates upon the inferior cornua of the thyreoid cartilage around an axis passing transversely through both joints. The gliding movement consists in a limited shifting of the cricoid on the thyreoid in different directions.

A pair of diarthrodial joints exist between the facets on the upper border of the lamina of the cricoid cartilage and the bases of the arytænoid cartilages; each joint is enclosed by an articular capsule, and a strong *posterior crico-arytænoid ligament* connects the cricoid cartilage with the medial and posterior part of the base of the arytænoid cartilage. These joints permit of two varieties of movement: one is a rotation of the arytænoid on a vertical axis, whereby the vocal process is moved lateralwards or medialwards, and the rima glottidis increased or diminished; the

other is a gliding movement, and allows the arytænoid cartilages to approach or recede from each other; from the direction and slope of the articular surfaces lateral gliding is accompanied by a forward and downward movement. The two movements of gliding and rotation are associated, the medial gliding being connected with medialward rotation, and the lateral gliding with lateralward rotation. The posterior crico-arytænoid ligaments limit the forward movements of the arytænoid cartilages on the cricoid cartilage.

A synchondrosis, sometimes a diarthrosis, exists between the apex of each arytænoid cartilage and the corresponding corniculate cartilage, and a Y-shaped ligament, the *ligamentum corniculopharyngeum*, unites the apices of the corniculate cartilages to the upper border of the lamina of the cricoid cartilage.

Ligaments and membranes.—The ligaments of the larynx (figs. 1022, 1023) are (*a*) *extrinsic*, those connecting the thyreoid cartilage and epiglottis with the hyoid bone, and the cricoid cartilage with the trachea; and (*b*) *intrinsic*, those uniting the cartilages of the larynx to each other.

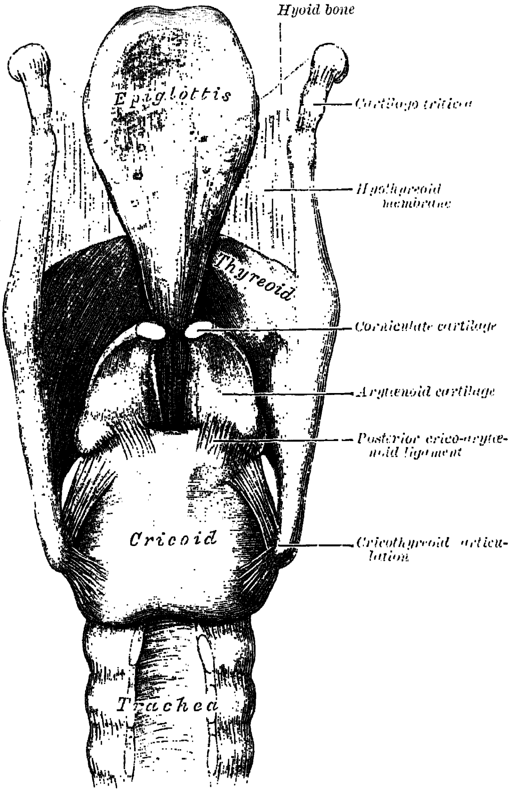


FIG. 1023.—The ligaments of the larynx. Posterior aspect.

Extrinsic ligaments.—The thyreoid cartilage is connected to the hyoid bone by the hyothyreoid membrane, and by a middle and two lateral hyothyreoid ligaments.

The *hyothyreoid membrane* is a broad, fibro-elastic layer, attached below to the upper border of the thyreoid cartilage and to the front of its superior cornua, and above to the upper margin of the posterior surface of the body and greater cornua of the hyoid bone, thus passing behind the posterior surface of the body of the hyoid bone, and being separated from it by a bursa mucosa, which facilitates the upward movement of the larynx during deglutition. The middle, thicker, part of the membrane is termed the *middle hyothyreoid ligament*; each of the lateral thinner portions is pierced by the superior laryngeal vessels and the internal branch of the superior laryngeal nerve. Its outer surface is in relation with the Thyreohyoideus, Sternohyoideus, and Omohyoideus, and with the body of the hyoid bone.

The *lateral hyothyreoid ligaments* are round elastic cords which form the posterior borders of the hyothyreoid membrane and connect the tips of the superior cornua of the thyreoid cartilage to the posterior ends of the greater cornua of the hyoid bone. A small cartilaginous nodule, the *cartilago triticea*, is frequently found in each ligament.

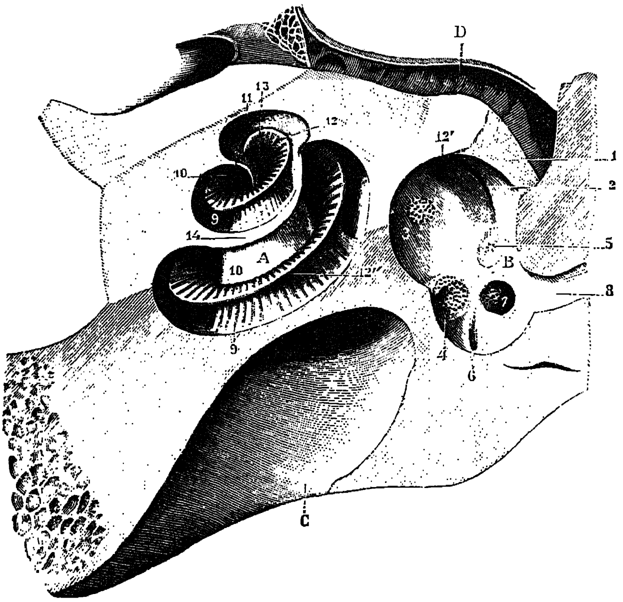
The epiglottis is attached to the hyoid bone by the hyo-epiglottic ligament, and to the thyreoid cartilage by the thyreo-epiglottic ligament (p. 1062).

The *cricotracheal ligament* unites the lower border of the cricoid cartilage with the first ring of the trachea. It is continuous below with the fibrous membrane which invests the rings of the trachea.

Intrinsic ligaments.—Beneath the mucous membrane of the larynx is a broad sheet of fibrous tissue containing many elastic fibres, and termed the *elastic membrane of the larynx*. It is subdivided on either side by the interval between the ventricular and vocal ligaments; the upper portion extends between the arytænoid cartilage and the cartilage of the epiglottis, and is often

from the base to the summit, where it ends in the *cupula*, which forms the apex of the cochlea. The beginning of this canal is about 3 mm. in diameter; it diverges from the modiolus towards the tympanic cavity and vestibule, and presents three openings. One, the *fenestra cochleæ*, communicates with the tympanic cavity and in the recent state is closed by the *secondary tympanic membrane*; another, of an elliptical form, opens into the vestibule. The third is the aperture of the aquæductus cochleæ, leading to a minute funnel-shaped canal which opens on the inferior surface of the petrous part of the temporal bone, transmits a small vein to join the inferior petrosal sinus, and establishes a communication between the subarachnoid cavity and the scala tympani.

FIG. 993.—The cochlea and vestibule. Exposed from above. (Testut.)



All the hard parts which form the roof of the internal ear have been removed with the saw. A. Cochlea. B. Vestibule. C. Internal acoustic meatus. D. Tympanic cavity. 1. Section of promontory. 2. Fissura vestibuli. 3. Recessus sphæricus. 4. Recessus ellipticus. 5. Fossa cochlearis. 6. Orifice of the aquæductus vestibuli. 7. Inferior opening of the posterior semicircular canal. 8. Non-ampullated end of lateral semicircular canal. 9. Scala tympani of the cochlea. 10. Scala vestibuli. 11. Cupula. 12. Osseous spiral lamina, with 12′, its vestibular origin; 12″, its external border. 13. Helicotrema. 14. Bony wall of cochlea.

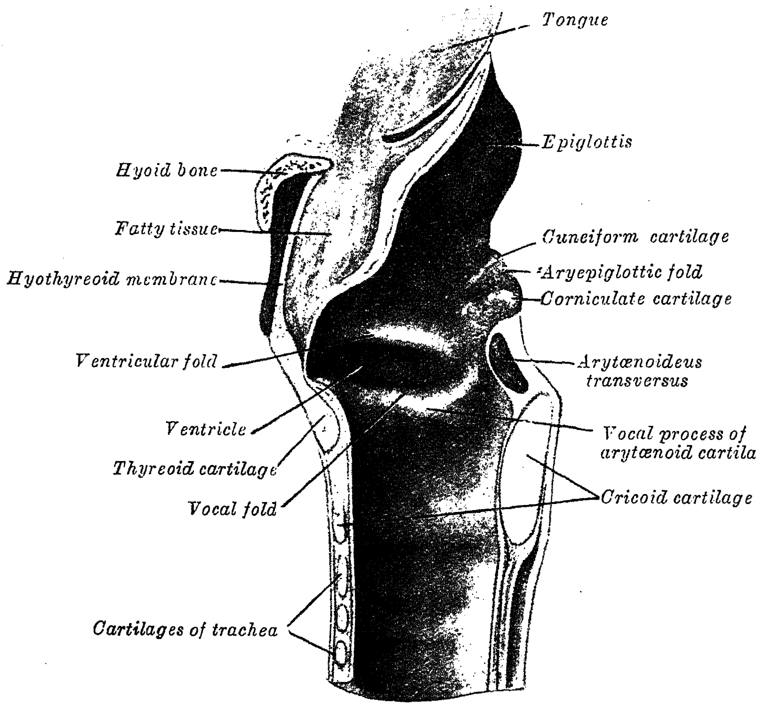
The *osseous spiral lamina* is a bony shelf or ledge which winds round and projects from the modiolus into the interior of the canal, like the thread of a screw. It reaches about halfway across the canal, and incompletely divides it into two passages or scalæ: an upper, named the *scala vestibuli*, and a lower, the *scala tympani*. The width of the osseous spiral lamina gradually decreases from the basal to the apical coil of the cochlea, and near the summit of the cochlea the lamina ends in a hook-shaped process, the *hamulus laminæ spiralis*; this assists in forming the boundary of a small opening, the *helicotrema*, through which the two scalæ communicate with each other. From the spiral canal of the modiolus numerous canals pass outwards through the osseous spiral lamina as far as its free edge and transmit branches of the cochlear nerve. In the lower part of the first turn of the cochlea a *secondary spiral lamina* projects inwards from the outer wall of the bony tube; it does not, however, reach the osseous spiral lamina, so that if the laminæ be viewed from the vestibule a narrow fissure, the *fissura vestibuli*, is seen between them.

The *osseous labyrinth* is lined by a thin fibroserous membrane which is closely adherent to the bone; the free surface of the membrane is smooth, and covered with a layer of epithelium. The osseous labyrinth is filled with

lower folds are concerned in the production of voice, and are therefore named the *vocal folds* (true vocal cords), and the fissure between them is called the *rima glottidis*.

The *entrance to the larynx* (aditus laryngis) (fig. 1026) is the aperture through which the laryngeal cavity opens into the pharynx. It slopes downwards and backwards, and is triangular in shape, with its base in front. It is bounded anteriorly by the upper edge of the epiglottis, posteriorly by the mucous membrane stretching between the arytænoid cartilages, and on either side by the free edge of a fold of mucous membrane, enclosing ligamentous and muscular fibres, stretched between the side of the epiglottis and the apex of the arytænoid cartilage; this is the *aryepiglottic fold*, and on the posterior part of its free

FIG. 1025.—A sagittal section through the larynx.



margin are two oval elevations, an anterior produced by the cuneiform cartilage, and a posterior by the corniculate cartilage. These elevations are separated by a shallow vertical furrow, which is continuous below with the opening into the ventricle of the larynx.

The *vestibule of the larynx* (figs. 1025, 1026) is the part between the laryngeal entrance and the level of the ventricular folds; it is wide above, and narrow below. Its anterior wall consists of the posterior surface of the epiglottis, the lower part of which projects backwards as the tubercle or cushion (p. 1063). Its lateral walls, deep in front and shallow behind, are formed by the medial surfaces of the aryepiglottic folds; its posterior wall consists of the mucous membrane connecting the arytænoid cartilages, above the level of the ventricular folds.

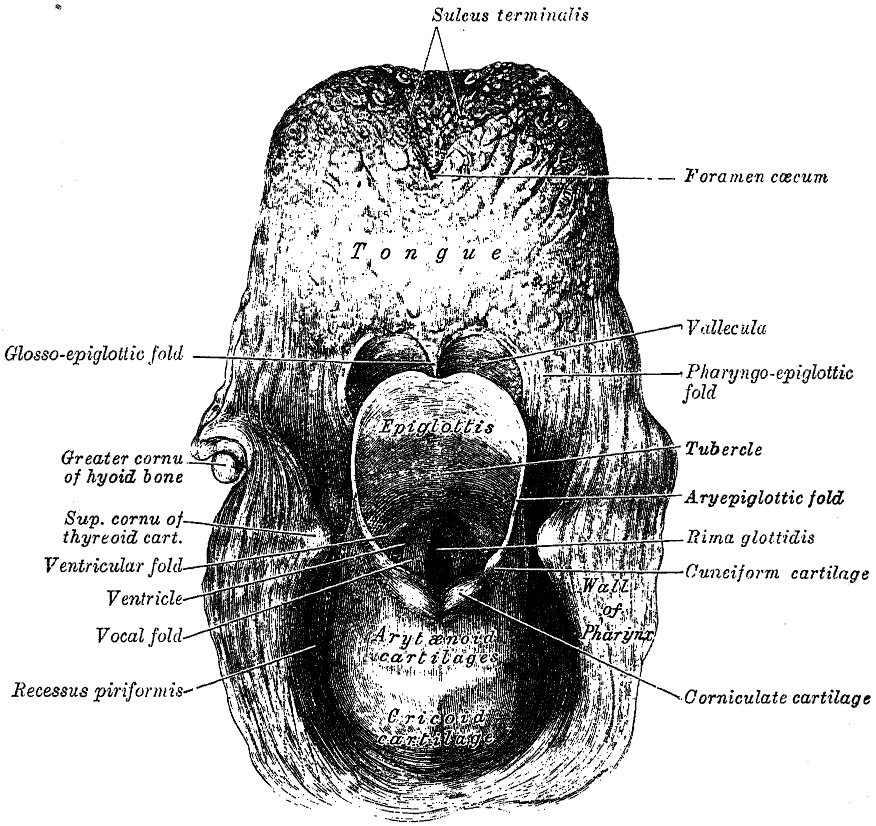
The *middle part* of the laryngeal cavity is the smallest. It reaches from the level of the rima vestibuli to that of the rima glottidis. On either side it opens, through a slit between the ventricular and vocal folds, into a recess which is named the ventricle of the larynx.

The *ventricular folds* (false vocal cords) (figs. 1024, 1025, 1027) are two thick folds of mucous membrane, each enclosing a narrow band of fibrous tissue, the ***ventricular ligament***, which is fixed in front to the angle of the thyreoid cartilage

immediately below the attachment of the epiglottic cartilage, and behind to the anterolateral surface of the arytænoid cartilage, a short distance above the vocal process.

The *vocal folds* (true vocal cords) (figs. 1024, 1025, 1027) are concerned in the production of sound, and enclose the vocal ligaments. Each *vocal ligament* consists of a band of yellow elastic tissue, attached in front to the angle of the thyreoid cartilage below the ventricular ligament, and behind to the vocal process of the arytænoid cartilage. It is continuous below with the lateral part of the conus elasticus. It is covered medially with mucous membrane, which is thin, and closely adherent to it. The Vocalis muscle lies lateral to and parallel with the vocal ligament.

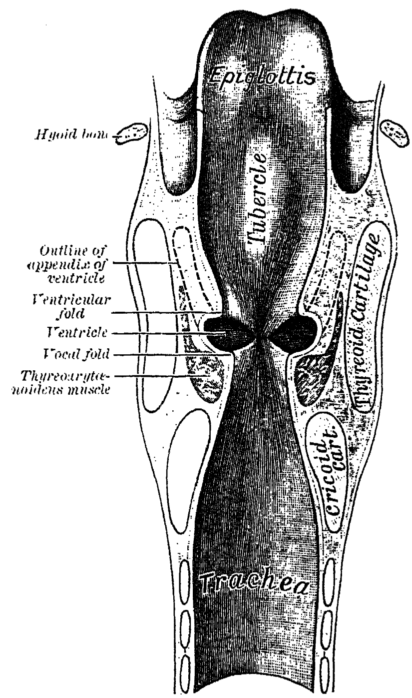
FIG. 1026.—The tongue and the entrance to the larynx. Posterior aspect.



The *rima glottidis* (figs. 1026, 1028) is a fissure situated between the vocal cords anteriorly, and between the bases and vocal processes of the arytænoid cartilages posteriorly; it is limited behind by the mucous membrane passing between the arytænoid cartilages, at the level of the vocal folds. The portion between the vocal folds is named the *intermembranous part* (glottis vocalis), and measures about three-fifths of the length of the entire aperture; that between the arytænoid cartilages is named the *intercartilaginous part* (glottis respiratoria). The average length of the rima glottidis, in the male, is 23 mm.; in the female, 17 mm. Its width and shape vary with the movements of the vocal folds and arytænoid cartilages during respiration and phonation. In the condition of rest, as in quiet respiration, the intermembranous part is triangular, with its apex in front and its base behind—the latter being represented by a line, about 8 mm. long, connecting the anterior ends of the vocal processes—while the medial surfaces of the arytænoid cartilages are parallel to each other and hence the intercartilaginous part is rectangular. During extreme adduction of the

vocal folds, as in the production of a high note, the intermembranous part of the rima glottidis is reduced to a linear slit by the apposition of the vocal folds, while the intercartilaginous part is triangular, its apex corresponding to the anterior ends of the vocal processes of the arytænoid cartilages, which are approximated by the medial rotation of the cartilages. Conversely in extreme abduction of the vocal folds, as in forced inspiration, the arytænoid cartilages and their vocal processes are rotated lateralwards, and the intercartilaginous part is triangular in shape but with its apex directed backwards. In this condition the rima glottidis is somewhat lozenge-shaped, the sides of the intermembranous part diverging from before backwards, those of the intercartilaginous part diverging from behind forwards—the widest part of the aperture corresponding with the attachments of the vocal folds to the vocal processes.

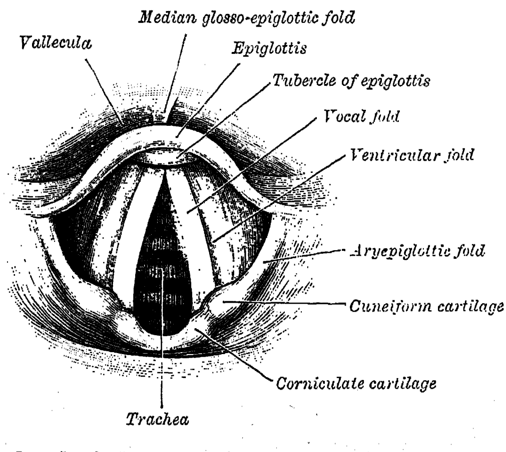
Fig. 1027.—A coronal section through the larynx and the upper part of the trachea.



The *ventricle of the larynx* (fig. 1025) is a fusiform recess on either side, between the ventricular and vocal folds, and ascending for a short distance outside the ventricular fold. It is lined with mucous membrane, lateral to which is the corresponding Thyreoarytænoideus muscle. From the anterior part of the ventricle a narrow opening leads upwards into the appendix of the ventricle.

The *appendix of the ventricle* (laryngeal saccule) (fig. 1027) is a pouch which ascends from the anterior part of the ventricle, between the ventricular fold and the inner surface of the thyreoid cartilage, occasionally extending as high as the upper border of the cartilage ; it is conical in form, and curved slightly backwards. On the surface of its mucous membrane are the openings of sixty or seventy mucous glands, which are lodged in the submucous areolar tissue. The appendix is enclosed in a fibrous capsule, continuous below with the ventricular ligament. Its medial surface is covered by a few delicate muscular fasciculi, which arise from the apex of the arytænoid cartilage and become lost in the aryepiglottic fold of mucous membrane ; laterally it is separated from the thyreoid cartilage by the Thyreoepiglotticus. These muscles compress the sac, and express the secretion of its glands upon the vocal fold to lubricate its surfaces.

Fig. 1028.—A laryngoscopic view of the interior of the larynx.



The *lower part* of the laryngeal cavity extends from the level of the vocal folds to the lower border of the cricoid cartilage. Its upper part is elliptical in form, but lower down it widens, assumes a circular shape, and is continuous with the cavity of the

trachea. It is lined with mucous membrane, and its walls consist of the conus elasticus above, and the inner surface of the cricoid cartilage below.

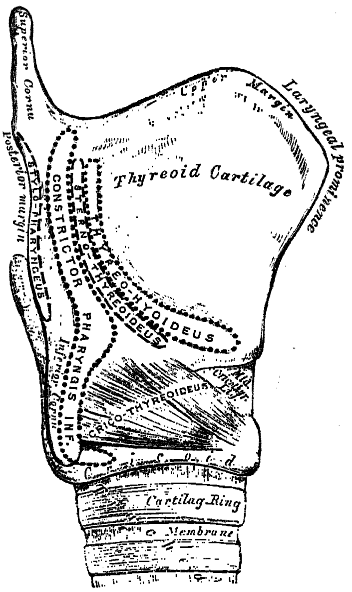
Muscles.—The muscles of the larynx are *extrinsic* and *intrinsic*. The extrinsic muscles pass between the larynx and neighbouring structures, and are described in the section on Myology. The intrinsic muscles are :

Cricothyreoideus,
  pars obliqua,
  pars recta.
Cricoarytænoideus posterior.
Cricoarytænoideus lateralis.
Arytænoideus transversus.
Arytænoideus obliquus.
Aryepiglotticus.
Thyreoarytænoideus.
Vocalis.
Thyreoepiglotticus.
Ventricularis.

With the exception of the Arytænoideus transversus these muscles are paired.

The *Cricothyreoideus* (fig. 1029), triangular in form, arises from the front and lateral part of the outer surface of the cricoid cartilage; its fibres diverge, and are arranged in two groups. The lower fibres constitute the *pars obliqua* and slant backwards and lateralwards to the anterior border of the inferior cornu, while the anterior fibres form the *pars recta* and run upwards and backwards to the posterior part of the lower border of the lamina, of the thyreoid cartilage.

Fig. 1029.—A side view of the larynx, showing the muscular attachments.



The medial borders of the two muscles are separated by a triangular interval occupied by the subcutaneous part of the middle cricothyreoid ligament.

The *Cricoarytænoideus posterior* (fig. 1030) arises from the lower and medial part of the broad depression on the corresponding half of the posterior surface of the lamina of the cricoid cartilage; its fibres, directed upwards and lateralwards, converge to be inserted into the back of the muscular process of the arytænoid cartilage. The highest fibres are nearly horizontal, the middle oblique, and the lowest almost vertical.

The *Cricoarytænoideus lateralis* (fig. 1031) is smaller than the preceding muscle; it arises from the upper border of the arch of the cricoid cartilage, and, passing obliquely upwards and backwards, is inserted into the front of the muscular process of the arytænoid cartilage.

The *Arytænoideus transversus* (fig. 1030) is a single muscle which bridges the interval between the arytænoid cartilages and fills the posterior concave surfaces of these cartilages. It arises from the back of the muscular process and lateral border of the arytænoid cartilage of one side, and is inserted into the corresponding parts of the cartilage on the opposite side.

The *Arytænoideus obliquus* (fig. 1030), superficial to the Arytænoideus transversus, consists of two fasciculi, which cross each other like the limbs of the letter X. Each passes from the back of the muscular process of one arytænoid cartilage to the apex of the opposite cartilage. A few fibres are continued round the lateral margin of the apex of the arytænoid cartilage, and are prolonged into the aryepiglottic fold; they constitute the *Aryepiglotticus* muscle.

The *Thyreoarytænoideus* (figs. 1031, 1032) is a broad, thin muscle, which is situated lateral to the vocal fold, the conus elasticus, the ventricle and the ventricular appendix. It arises in front from the lower half of the angle of the thyreoid cartilage, and from the middle cricothyreoid ligament. Its fibres pass backwards and lateralwards, to be inserted into the anterolateral surface

of the arytænoid cartilage. The lower and deeper fibres of the muscle form a band which, in a coronal section, appears as a triangular bundle, and is attached to the lateral surface of the vocal process and to the inferior fovea on the

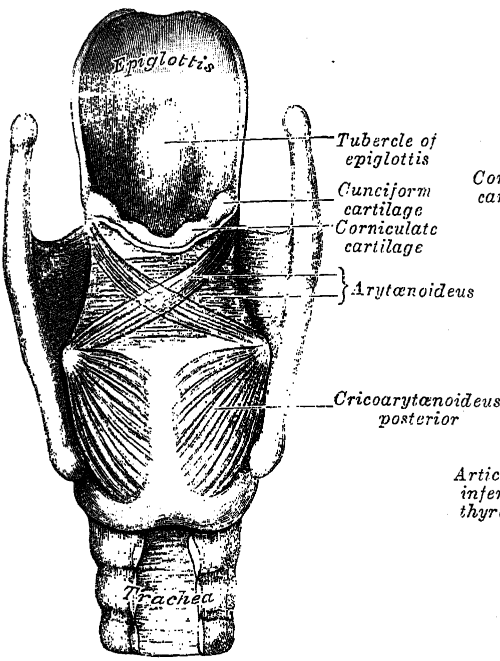


FIG. 1030.—The muscles of the larynx. Posterior aspect.

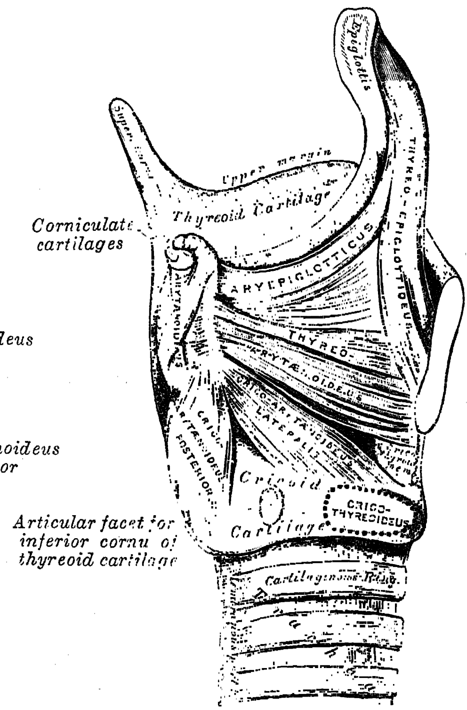


FIG. 1031.—The muscles of the larynx. Lateral aspect. The right lamina of the thyreoid cartilage has been removed.

anterolateral surface of the arytænoid cartilage. This bundle is named the *Vocalis* muscle, and is parallel with, and just lateral to, the vocal ligament. The Vocalis is thicker behind than in front, because some of its fibres are inserted into the vocal ligament, and so fail to reach the thyreoid cartilage. A considerable number of the fibres of the Thyreoarytænoideus are prolonged into the aryepiglottic fold, where some of them are lost, while others are continued to the margin of the epiglottis, forming the *Thyreoepiglotticus*. A few fibres extend along the wall of the ventricle from the lateral margin of the arytænoid cartilage to the side of the epiglottis, and constitute the *Ventricularis* muscle.

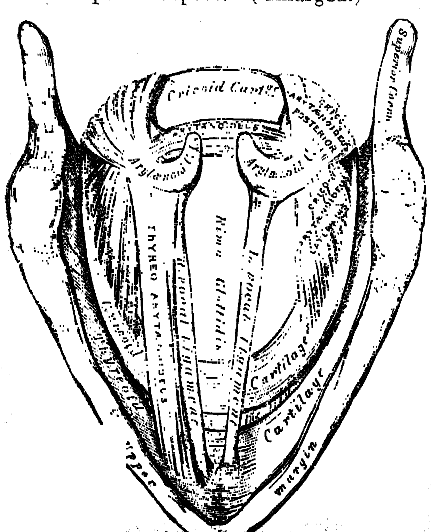


FIG. 1032.—The muscles of the larynx. Superior aspect. (Enlarged.)

Actions.—The muscles of the larynx may be conveniently divided into two groups, (1) those which open and close the glottis, viz. the Cricoarytænoidei posteriores et laterales and the Arytænoidei; (2) those which regulate the degree of tension of the vocal ligaments, viz. the Cricothyreoidei, the Thyreoarytænoidei, and the Vocales.

The *Cricoarytænoidei posteriores* open the glottis, by rotating the arytænoid cartilages outwards around a vertical axis passing through the crico-arytænoid joints, so that the vocal processes and the attached vocal folds are separated.

The *Cricoarytænoidei laterales* close the glottis, by rotating the arytænoid cartilages inwards so as to approximate the vocal processes.

The *Arytænoideus transversus* approximates the arytænoid cartilages, and thus closes the opening of the glottis, especially at its posterior part.

The *Arytænoidei obliqui* and the *Aryepiglottici* act as a sphincter of the entrance of the larynx, by bringing the aryepiglottic folds together, and by approximating the arytænoid cartilages to the tubercle or cushion of the epiglottis.

The *Cricothyreoidei* produce tension and elongation of the vocal ligaments by drawing up the arch of the cricoid cartilage and tilting back the upper border of its lamina; the distance between the vocal processes and the angle of the thyreoid is thus increased, and the vocal ligaments are consequently elongated.

The *Thyreoarytænoidei* draw the arytænoid cartilages forwards towards the thyreoid, and thus shorten and relax the vocal ligaments. At the same time they rotate the arytænoid cartilages inwards and approximate the vocal folds. The deeper fibres, forming the *Vocales*, produce relaxation of the vocal ligaments.

The manner in which the entrance of the larynx is closed during deglutition is referred to on p. 1122.

Mucous Membrane.—The mucous membrane of the larynx is continuous above with that of the mouth and pharynx, below with that of the trachea. It is loosely attached to the anterior surface of the epiglottis, and to the underlying tissues in the valleculæ. It covers the aryepiglottic folds which bound the entrance of the larynx; in these folds there is a considerable amount of areolar tissue. It lines the cavity of the larynx; forms, by its reduplication, the chief parts of the ventricular folds, and is continued from the ventricle into the ventricular appendix. It is firmly attached to the posterior surface of the epiglottis and to the laryngeal surfaces of the cuneiform and arytænoid cartilages. The parts covering the vocal ligaments are thin and intimately adherent to them. On the anterior surface, and the upper half of the posterior surface, of the epiglottis, the upper part of the aryepiglottic folds, and the vocal folds, the epithelium of the mucous membrane is of the stratified squamous type; patches of stratified squamous epithelium are also found above the glottis. The rest of the laryngeal mucous membrane is covered by columnar ciliated epithelium.

Glands.—The mucous membrane of the larynx is furnished with numerous mucous glands; they are very plentiful upon the epiglottis, where they are lodged in little pits; many are present in the margins of the aryepiglottic folds in front of the arytænoid cartilages, where they are termed the *arytænoid glands*. They are large and numerous in the ventricular appendices. The free edges of the vocal folds are devoid of glands.

Taste-buds, similar to those in the tongue, are scattered over the posterior surface of the epiglottis, in the aryepiglottic folds, and less regularly in some other parts of the larynx.

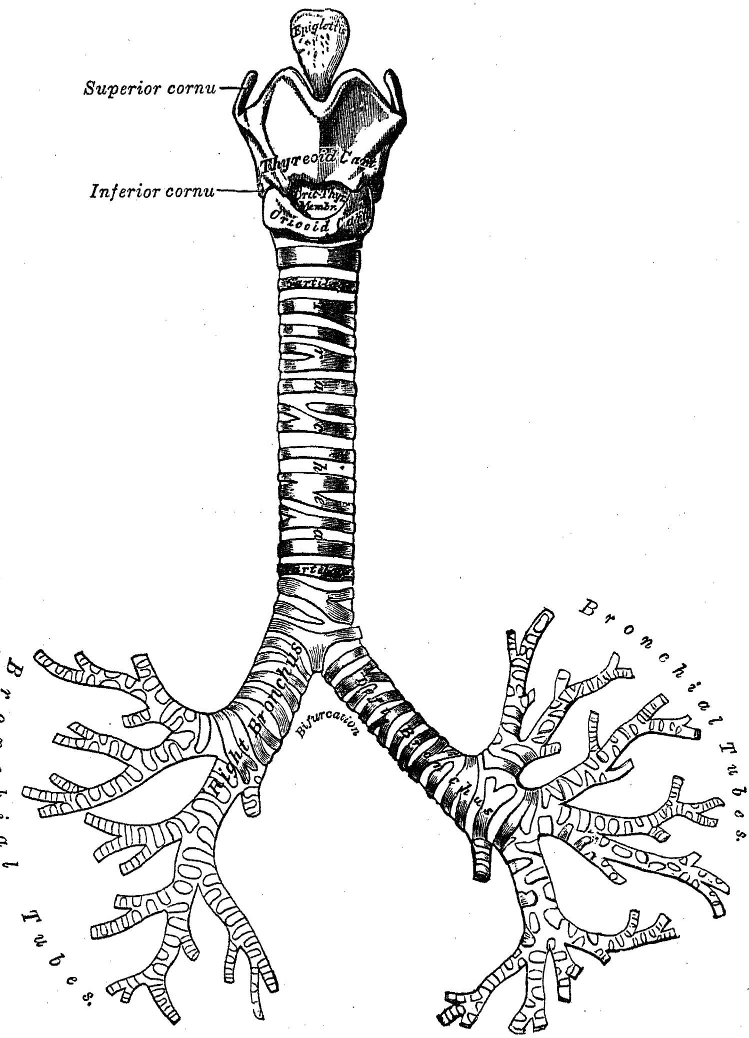
Vessels and Nerves.—The chief *arteries* of the larynx are the laryngeal branches of the superior and inferior thyreoid arteries. The *veins* accompanying the superior laryngeal artery join the superior thyreoid vein which opens into the internal jugular vein; those accompanying the inferior laryngeal artery join the inferior thyreoid vein which opens into the innominate vein. The *lymphatic vessels* are divisible into two sets, a superior above, and an inferior below, the vocal folds; the superior vessels accompany the superior laryngeal artery, pierce the hyothyreoid membrane, and end in the deep cervical lymph-glands situated near the bifurcation of the common carotid artery; some of the inferior lymphatic vessels pierce the middle cricothyreoid ligament and open into a lymph-gland lying in front of that ligament or in front of the upper part of the trachea, while others emerge below the cricoid cartilage and pass to the deep cervical lymph-glands and to the lymph-glands alongside of the inferior thyreoid artery. The *nerves* are derived from the internal and external branches of the superior laryngeal nerve, from the recurrent nerve and from the sympathetic. The internal laryngeal branch is almost entirely sensory, but some motor filaments are said to be carried by it to the Arytænoideus. It enters the larynx through the postero-inferior part of the hyothyreoid membrane above the superior laryngeal artery, and divides into three branches; one is distributed to both surfaces of the epiglottis, a second to the aryepiglottic fold, and a third, the largest, supplies the mucous membrane over the back of the larynx and communicates with the recurrent nerve. The external laryngeal branch supplies the Cricothyreoideus by entering its lateral surface. The recurrent nerve accompanies the laryngeal branch of the inferior thyreoid artery, and passes upwards beneath the lower border of the Constrictor pharyngis inferior, immediately behind the cricothyreoid joint. It supplies all the intrinsic muscles of the larynx except the Cricothyreoideus, and a part of the Arytænoideus (pp. 919, 920). The sensory branches of the laryngeal nerves form subepithelial plexuses, from which fibres pass to end between the cells covering the mucous membrane.*

* Consult an article 'On the nerves of the human larynx' by T. F. M. Dilworth, *Journal of Anatomy*, vol. lvi. 1921.

The Trachea and Bronchi (fig. 1033)

The **trachea, or windpipe,** is a cartilaginous and membranous tube, about 10 or 11 cm. long, continued downwards from the lower part of the larynx, and reaching from the level of the sixth cervical vertebra to that of the upper border

Fig. 1033.—The cartilages of the larynx, trachea, and bronchi. Anterior aspect.

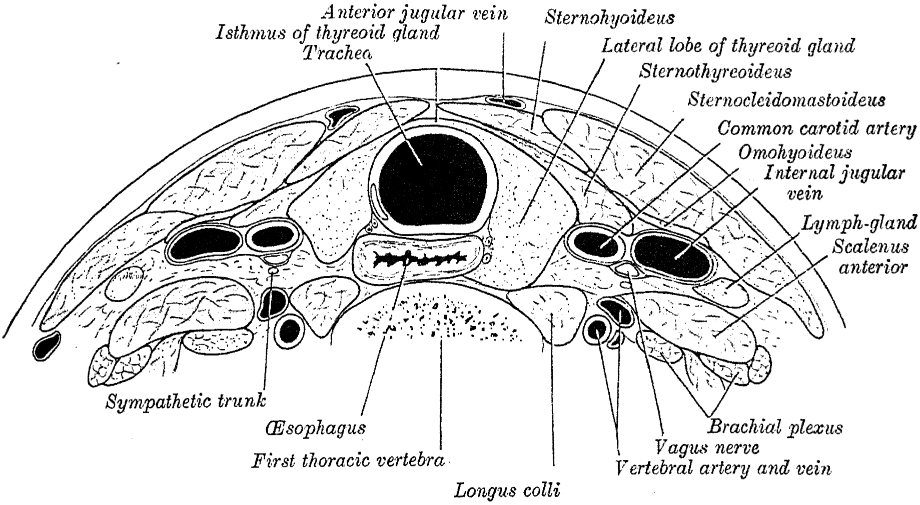


of the fifth thoracic vertebra, where it divides into two bronchi, one for each lung. It is not quite cylindrical, being flattened posteriorly; its diameter from side to side, is about 2 cm. in the male, and 1·5 in the female. In the child the trachea is smaller, more deeply placed and more movable than in the adult.

Relations of the trachea.—*In front* of the *cervical part* of the trachea (fig. 1034) are the skin, the superficial and deep fasciæ, the venous jugular arch connecting the anterior jugular veins, the Sternohyoidei and Sternothyreoidei. The second, third and fourth rings of the trachea are crossed by the isthmus of the thyreoid gland, and immediately above the isthmus is an anastomosis between the two superior thyreoid arteries; below the isthmus are the pretracheal fascia, the inferior thyreoid veins, the remains of the thymus, and the

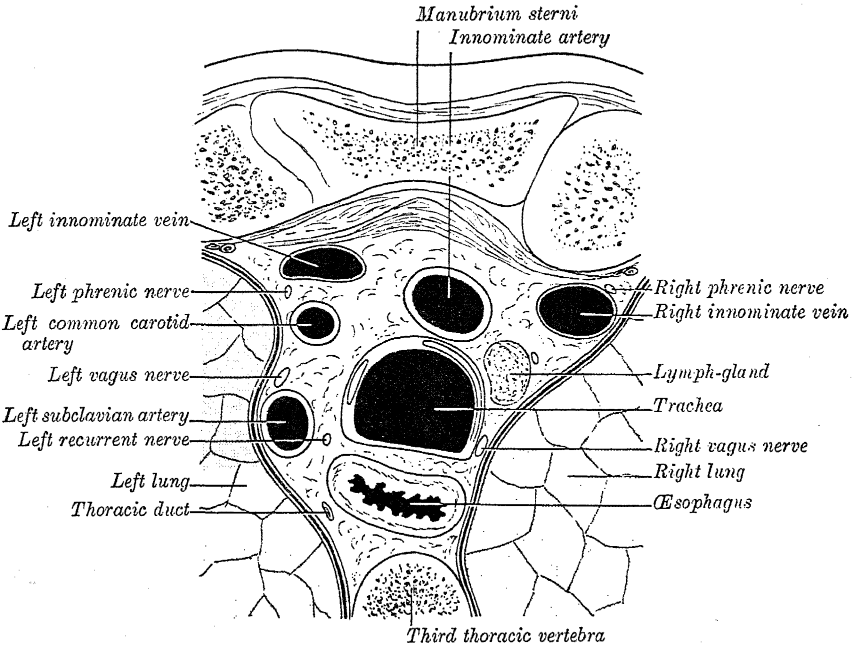
arteria thyreoidea ima (when that vessel exists). In the child, the innominate artery crosses obliquely in front of the trachea at, or a little above, the level

FIG. 1034.—A transverse section through the anterior part of the neck at the level of the body of the first thoracic vertebra.



of the upper border of the manubrium sterni. *Behind* the trachea is the œsophagus, which separates the trachea from the vertebral column; the recurrent nerves ascend, one on either side, in the grooves between the sides of the trachea

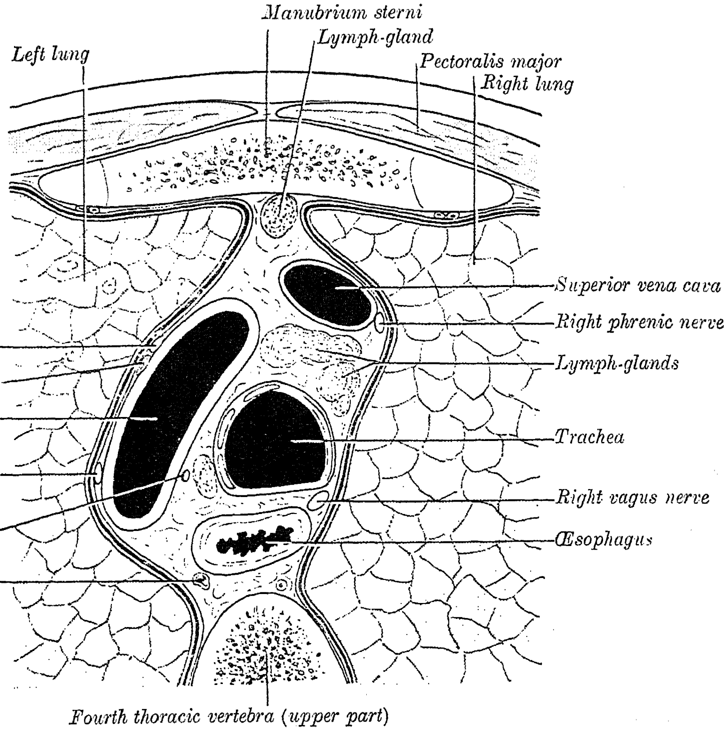
FIG. 1035.—A transverse section through the mediastinal cavity at the level of the body of the third thoracic vertebra.



and the œsophagus. *Lateral* to the trachea are the lobes of the thyreoid gland, which descend to the level of the fifth or sixth tracheal ring, the common carotid and inferior thyreoid arteries.

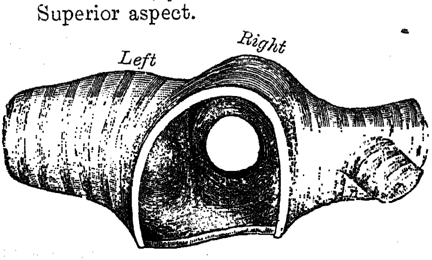
The *thoracic part* of the trachea (figs. 1035, 1036) descends through the posterior part of the superior mediastinal cavity. *In front* of its *upper* portion are the manubrium sterni, the origins of the Sternothyreoidei, the remains of the thymus, and the inferior thyreoid veins; and in front of its *lower* portion

FIG. 1036.—A transverse section through the mediastinal cavity at the level of the upper part of the body of the fourth thoracic vertebra.



are the left innominate vein, the arch of the aorta, the innominate and left carotid arteries, the deep part of the cardiac plexus of nerves, and some lymph-glands. Owing to the divergence of the innominate artery from the left common carotid as they ascend in the neck, the former vessel comes to lie on the right, and the latter on the left of the trachea. *Behind* is the œsophagus, which intervenes between the trachea and the vertebral column. On the *right* are the right lung and pleura, the right vagus nerve, and the azygos vein. On the *left* are the arch of the aorta, the left common carotid and left sub-clavian arteries. The left recurrent nerve, in its upward course, lies at first between the trachea and the arch of the aorta, and then in the groove between the trachea and the œsophagus.

FIG. 1037.—A transverse section through the trachea, just above its bifurcation. Superior aspect.



The **right bronchus**, wider, shorter, and more vertical than the left, is about 2·5 cm. long, and enters the right lung nearly opposite the fifth thoracic vertebra. The azygos vein arches over it from behind; and the right pulmonary artery lies at first below and then in front of it. It gives off a branch to the upper lobe of the right lung; this is termed the *eparterial branch*, because it arises above the right pulmonary artery. The bronchus now

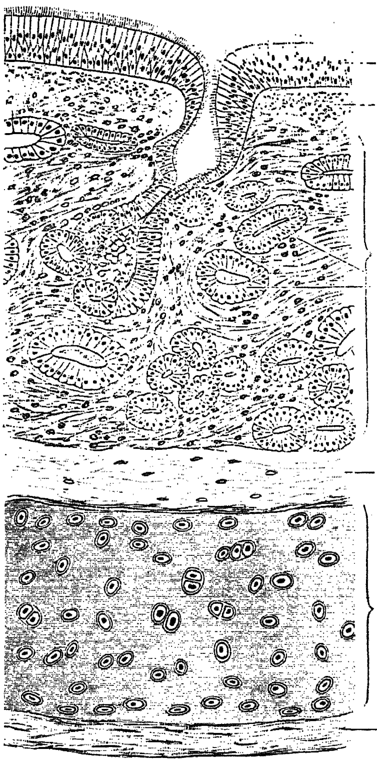
passes below the artery, and is known as the *hyparterial branch* ; this divides into two branches for the middle and lower lobes of the lung.

The **left bronchus**, narrower than the right, is nearly 5 cm. long, and enters the root of the left lung opposite the sixth thoracic vertebra. It passes beneath the aortic arch, and crosses in front of the œsophagus, the thoracic duct, and the descending aorta ; the left pulmonary artery lies at first above, and then in front of it. The left bronchus has no eparterial branch, and therefore it has been supposed by some anatomists that there is no upper lobe to the left lung, and that the so-called upper lobe of the left lung corresponds to the middle lobe of the right lung.

The further subdivision of the bronchi will be considered with the structure of the lung.

If the trachea be cut across a short distance above its bifurcation, and the interior of the lower part viewed from above (fig. 1037), it will be seen that the septum between the two bronchi lies on the left of the median plane, and that the right bronchus is a more direct continuation of the trachea than the left.

FIG. 1038.—A transverse section through a part of the wall of the trachea.



Structure (fig. 1038).—The trachea and extrapulmonary bronchi consist of a framework of imperfect rings of hyaline cartilage, united by fibrous and unstriped muscular tissue. They are lined by mucous membrane.

The *cartilages* of the trachea vary from sixteen to twenty in number. Each is in an imperfect ring which occupies the anterior two-thirds or so of the circumference of the trachea ; behind, where the rings are deficient, the tube is flat, and is completed by fibrous tissue and unstriped muscular fibres. The cartilages are placed horizontally above one another, and are separated by narrow intervals. They measure about 4 mm. in depth and 1 mm. in thickness ; their external surfaces are flattened in a vertical direction, but their internal are convex. Two or more of the cartilages often unite, partially or completely, and are sometimes bifurcated at their extremities. They are highly elastic, but may become calcified in advanced life. In the bronchi the cartilages are shorter and narrower than those of the trachea, but have the same shape and arrangement.

The first and the last tracheal cartilages differ from the others (fig. 1033). The *first cartilage* is broader than the rest, and often divided at one end; it is connected by the cricotracheal ligament with the lower border of the cricoid cartilage, with which, or with the succeeding cartilage, it is sometimes blended. The *last cartilage* is thick and broad in the middle, in consequence of its lower border being prolonged into a triangular hook-shaped process which curves downwards and backwards between the two bronchi. It forms on each side an imperfect ring which encloses the commencement of the bronchus. The cartilage above the last is somewhat broader at its centre than the others.

The *fibrous membrane*.—The cartilages are enclosed in an elastic fibrous membrane, which consists of two layers, one, the thicker, passing over the outer surfaces of the rings, the other over the inner surfaces : at the upper and lower margins of the cartilages the two layers blend and form a stout membrane which connects the rings one with another. Where the cartilages are deficient posteriorly, the membrane forms a single layer.

The *muscular tissue* is placed within the fibrous membrane at the posterior part of the tube, and consists of two layers of non-striped muscle, longitudinal and transverse. The *longitudinal fibres* are external, and consist of a few scattered bundles. The *transverse fibres* (Trachealis muscle) are internal, and form a thin layer which not only extends

between the ends of the cartilages but also passes across in the intervals between the cartilages.

Mucous Membrane.—The mucous membrane is continuous above with that of the larynx, and below with that of the bronchi. It consists of areolar and lymphoid tissue, and presents a well-marked basement-membrane, supporting a stratified epithelium, the surface cells of which are columnar and ciliated, while those of the deeper layers are oval or round. Beneath the basement-membrane there is a layer of longitudinal elastic fibres with a small amount of intervening areolar tissue. The *submucous layer* is composed of a loose meshwork of connective tissue, containing large blood-vessels, nerves, and mucous glands; the ducts of the latter pierce the overlying layers and open into the trachea (fig. 1038).

Vessels and Nerves.—The trachea is supplied with blood mainly by the inferior thyreoid *arteries*. The *veins* end in the thyreoid venous plexus. The *nerves* are derived from the vagi and the recurrent nerves, and from the sympathetic trunks; they are distributed to the Trachealis muscle and between the epithelial cells.

Applied Anatomy.—Foreign bodies often find their way into the air-passages, and may consist of large soft substances, as pieces of meat, which may become lodged in the entrance of the larynx, or in the rima glottidis, and cause speedy suffocation unless rapidly got rid of, or unless an opening is made into the air-passages below the obstruction, so as to enable the patient to breathe. Smaller bodies, frequently of a hard nature, such as cherry or plum stones, small pieces of bone, buttons, &c., may find their way through the rima glottidis into the trachea or bronchi, or may lodge in the ventricle of the larynx. The dangers then depend not so much upon the mechanical obstruction as upon reflex spasm of the glottis produced by the irritation of the foreign body. When lodged in the ventricle of the larynx, the foreign body may produce few symptoms, beyond sudden loss of voice or alteration in the voice sounds. When, however, it is situated in the trachea, it is constantly striking against the vocal folds during expiratory efforts, and thus produces attacks of dyspnœa from spasm of the glottis. When lodged in the bronchus, it usually becomes fixed there, and, occluding the lumen of the tube, causes a loss of the respiratory murmur on the affected side, and may subsequently lead to purulent bronchitis and gangrene of the lung.

Beneath the mucous membrane of the upper part of the air-passages there is a considerable amount of submucous tissue, which is liable to become much swollen from effusion in inflammatory affections, constituting the condition known as 'œdema of the glottis.' This effusion does not extend below the level of the vocal folds, on account of the fact that the mucous membrane is closely adherent to these structures without the intervention of any submucous tissue. In cases of œdema of the glottis, in which it is necessary to open the air-passages to prevent suffocation, the operation of laryngotomy is sufficient.

The air-passages may be opened in three different situations: by a vertical incision through the centre of the thyreoid cartilage (*thyreotomy*); through the middle cricothyreoid ligament (*laryngotomy*); or in some part of the trachea (*tracheotomy*).

Thyreotomy is usually performed for the purpose of removing growths from the vocal folds or for extracting foreign bodies from the ventricle of the larynx. A median incision is made from the upper border of the body of the hyoid bone to the lower border of the cricoid cartilage, and is carried through the subcutaneous tissues and deep fascia between the margins of the Sternohyoidei. An incision is then made in the middle cricothyreoid ligament, and one blade of a stout, sharp-pointed pair of scissors is introduced beneath the lower border of the thyreoid cartilage, and this structure is divided from below upwards. Great care must be taken to cut exactly in the middle line to avoid wounding the vocal folds. If the halves of the cartilage are now drawn apart, a very good view of the interior of the larynx will be obtained.

Laryngotomy is a simple operation, and should be performed in those cases where the air-passages require to be opened in an emergency for the relief of some sudden obstruction to respiration. The middle cricothyreoid ligament is very superficial, being covered only by the skin, superficial fascia, and the deep fascia in the middle line. On either side it is also covered by the Sternohyoideus and Sternothyreoideus, which diverge from each other at their upper parts, leaving a slight interval between them. On these muscles rest the anterior jugular veins. The cricothyreoid artery crosses the middle cricothyreoid ligament, and may be wounded, but rarely gives rise to any trouble. The operation is performed thus: the head being thrown back and steadied by an assistant, the finger is passed over the front of the neck, and the cricothyreoid depression felt for. A vertical incision is then made through the skin in the middle line over this spot, and carried down through the fascia until the middle cricothyreoid ligament is exposed. A cross-cut is then made through the ligament close to the upper border of the cricoid cartilage, so as to avoid, if possible, the cricothyreoid artery, and a laryngotomy tube inserted. It has been recommended, as a more rapid way of performing the operation, to make a transverse instead of a longitudinal cut through the superficial structures, and thus to open at once the air-passages. It will be seen, however, that in operating in this way the anterior jugular veins are in danger of being wounded.

Tracheotomy may be performed either above or below the isthmus of the thyreoid gland, or this structure may be divided and the trachea opened behind it. From the relations already described it must be evident that the trachea can be more readily opened above than below the isthmus.

Tracheotomy above the isthmus is performed thus: the patient should, if possible, be laid on his back on a table in a good light. A pillow is to be placed under the shoulders and the head thrown back and steadied by an assistant. The surgeon standing on the right side of his patient makes an incision from 4 cm. to 5 cm. long in the median line of the neck from the top of the cricoid cartilage. After the superficial structures have been divided, the interval between the Sternohyoidei must be found, the fascia divided, and the muscles drawn apart. The lower border of the cricoid cartilage must now be felt for, and the upper part of the trachea exposed from this point downwards in the middle line. It has been recommended that the layer of fascia in front of the trachea should be divided transversely at the level of the lower border of the cricoid cartilage, and, having been seized with a pair of forceps, pressed downwards with the handle of the scalpel. By this means the isthmus of the thyreoid gland is depressed, and is saved from all danger of being wounded, and the trachea cleanly exposed. The trachea is now transfixed with a sharp hook and drawn forwards in order to steady it, and is then opened by inserting the knife into it and dividing the upper two or three rings by cutting upwards. If the trachea is to be opened beneath the isthmus of the thyreoid gland, the incision must be made from a little below the cricoid cartilage to the top of the sternum; in this situation the trachea is situated more deeply.

A portion or the whole of the larynx may be removed for malignant disease. It may be removed by a median incision through the soft parts, freeing the cartilages from the muscles and other structures in front, separating the larynx from the trachea below, and dissecting it off from the deeper structures from below upwards.

The Pleuræ

Each lung is invested by a delicate serous membrane, the **pleura**, which is arranged in the form of a closed invaginated sac. A portion of the serous membrane covers the surface of the lung and dips into the fissures between its lobes; it is called the *pulmonary pleura*. The rest of the membrane lines the inner surface of the corresponding half of the chest-wall, covers the Diaphragm, and is reflected over the structures occupying the middle part of the thorax; this portion is termed the *parietal pleura*. The pulmonary and parietal pleuræ are continuous with one another around and below the root of the lung; in health they are in actual contact, but the potential space between them is known as the *pleural cavity*. When the lung collapses or when air or fluid collects between the pulmonary and parietal pleuræ, the pleural cavity becomes apparent. The right and left pleural sacs are distinct from one another, and only touch each other for a short distance behind the second and third pieces of the sternum. The interval between the two sacs is termed the mediastinal cavity. The right pleural sac is shorter, wider, and reaches higher in the neck than the left.

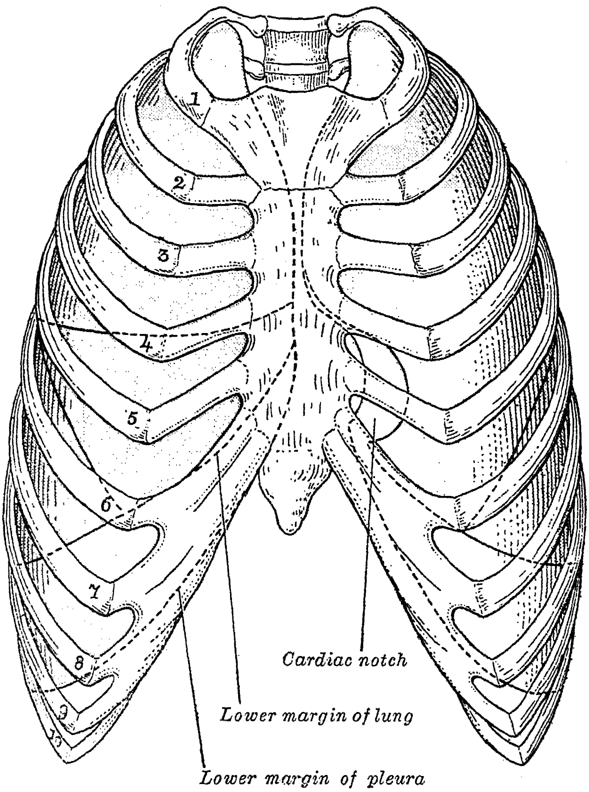
The **pulmonary pleura** is inseparably connected with the lung. It covers the surfaces of the lung, including those which bound the fissures between the lobes of the lung; it is wanting, however, over an area where the lung root enters, and along a line extending downwards from this and marking the attachment of the pulmonary ligament.

The **parietal pleura**.—Different portions of the parietal pleura have received distinctive names; the part lining the inner surfaces of the ribs and Intercostales is the *costal pleura*; that clothing the thoracic surface of the Diaphragm is the *diaphragmatic pleura*; that ascending into the neck over the summit of the lung is the *cupula of the pleura*; and that applied to the structures in the middle of the thorax is the *mediastinal pleura*.

The *costal pleura* (figs. 1039, 1040) lines the ribs and intercostal muscles, and is easily separated from them. In front it begins behind the sternum where it is continuous with the mediastinal pleura. The line of junction of the mediastinal with the costal pleura extends from behind the sternoclavicular joint downwards and medialwards to a point in the middle line behind the sternal angle. From this point the right and left costal pleuræ descend in contact with each other as far as the level of the fourth costal cartilages, below which the line differs on the two sides. On the right side it is continued down to the posterior surface of the xiphoid process. On the left it diverges lateralwards and descends close to or a short distance from the lateral margin of the

sternum, to the level of the sixth costal cartilage. On either side the costal pleura sweeps lateralwards, lining the inner surfaces of the costal cartilages, ribs and intercostales, and at the back of the thorax passes over the sympathetic trunk and its branches, and on to the sides of the bodies of the vertebræ, where it again becomes continuous with the mediastinal pleura. Above, the costal pleura is continuous with the cupula of the pleura at the inner margin of the first rib. Below, it is continuous with the diaphragmatic pleura along a line which differs slightly on the two sides. On the right side the line begins behind the xiphoid process, and runs downwards and backwards behind the seventh costal cartilage, and reaches the midaxillary line at the

FIG. 1039.—The relations of the pleuræ and lungs to the chest wall. Anterior aspect.



Pleuræ in blue ; lungs in purple.

level of the tenth rib ; from here the line ascends slightly, and crossing the twelfth rib, reaches the level of the spinous process of the twelfth thoracic vertebra. On the left side the line follows at first the ascending part of the sixth costal cartilage, but in the rest of its course is slightly lower than that on the right side.

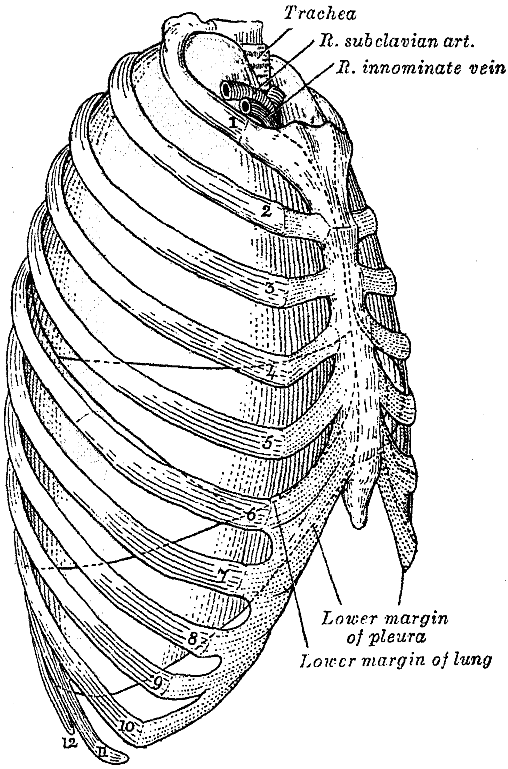
The *diaphragmatic pleura* is thin, and covers the upper surface of its corresponding side of the Diaphragm. The outer part of its circumference is the line described above, along which it is continuous with the costal pleura. Medially it is continuous with the mediastinal pleura along the line of attachment of the pericardium to the Diaphragm.

The *cupula of the pleura*, i.e. the cervical portion of the pleura, is the continuation of the costal pleura over the apex of the lung. It extends from the inner border of the first rib medialwards and upwards to the apex of the lung, its summit reaching as high as the lower edge of the neck of the first rib ; it then descends along the side of the trachea to become continuous with the

mediastinal pleura. The cupula of the pleura is strengthened by a dome-like expansion of fascia (*Sibson's fascia*) attached in front to the inner border of the first rib and behind to the anterior border of the transverse process of the seventh cervical vertebra; it is covered and strengthened by a few spreading muscular fibres derived from the Scaleni. The subclavian artery, directed upwards and lateralwards, occupies a furrow a little below the summit of the cupula.

The *mediastinal pleura*. The space between the pleuræ is named the mediastinal cavity or interpleural space. It contains the heart, enclosed in its pericardium, the great vessels entering and leaving the heart, and the œsophagus, together with other structures described on pp. 1080 to 1083. These are partly covered with the mediastinal pleura which consists of a right and a left portion (figs. 1036, 1041). Above the root of the lung each portion is a continuous sheet between the sternum and the vertebral column. That of the right side is in contact with the right innominate vein, the upper part of the superior vena cava, the terminal part of the azygos vein, the right phrenic and right vagus nerves, the trachea, and the œsophagus. That of the left side is in relation with the arch of the aorta, the left phrenic and left vagus nerves, the left innominate and superior intercostal veins, the left common carotid and subclavian arteries, the thoracic duct and the œsophagus. At the root of the lung the mediastinal pleura is carried lateralwards as a tube of serous membrane enclosing the structures of the lung-root and passing into continuity with the pulmonary pleura. Below the lung-root the mediastinal pleura extends as a bilaminar layer from the side of the pericardium to the mediastinal surface of the lung, where it is also continuous with the pulmonary pleura. This bilaminar layer is named the *pulmonary ligament* (fig. 1045), and serves to retain the lower part of the lung in position. It is continuous above with the tube investing the lung root; below it ends in a free falciform border.

FIG. 1040.—The relations of the pleuræ and lungs to the chest wall. Lateral aspect.



Pleuræ in blue; lungs in purple.

The inferior limit of the pleura is on a considerably lower level than the corresponding border of the lung (figs. 1039, 1040), but does not extend to the attachment of the Diaphragm, so that below the line of reflection of the pleura from the chest-wall to the Diaphragm, the latter is in direct contact with the rib cartilages and the Intercostales interni. Moreover, in ordinary inspiration the thin inferior margin of the lung does not extend as low as the line of the pleural reflection, with the result that the costal and diaphragmatic pleuræ are here in contact, the intervening narrow slit being termed the *phrenicocostal sinus*. A similar condition exists behind the sternum and rib cartilages, where the anterior thin margin of the lung falls short of the line of pleural reflection, and where the slit-like cavity between the two layers of pleura forms what is called the *costomediastinal sinus*.

Structure.—The free surface of the pleura is smooth, and moistened by serous fluid. Like other serous membranes, it is covered by a single layer of flattened nucleated cells, united at their edges by cement-substance. These cells are modified connective tissue corpuscles, and rest on a basement-membrane. Beneath the basement-membrane there are networks of yellow elastic and white fibres, imbedded in ground-substance which also contains connective tissue cells. Blood-vessels, lymphatic vessels, and nerves are distributed in the substance of the pleura, and the lymphatic vessels communicate with the pleural cavity by means of stomata or openings between the flattened cells.

Vessels and Nerves.—The *arteries* of the pleura are derived from the intercostal, internal mammary, musculophrenic, thymic, pericardiac, and bronchial vessels. The *veins* correspond to the arteries. The *lymphatics* are described on p. 778. The *nerves* are derived from the phrenic nerve and from the sympathetic trunk. Kölliker states that nerves accompany the ramifications of the bronchial arteries in the pulmonary pleura.

Applied Anatomy.—Acute inflammation of the pleura, or *pleurisy*, may be either dry or wet, and, if wet, either serous or purulent. *Dry pleurisy* is common in pneumonia, and is often an early manifestation of tuberculosis. It gives rise to much pain, and to friction sounds due to the scraping to and fro over one another of the inflamed and roughened parietal and pulmonary pleuræ. *Wet pleurisy* occurs if the inflammation causes the effusion of serum into the pleural cavity. The two pleural layers are now separated by the fluid effusion, so the friction sounds are no longer produced. Room is found for the fluid by shrinkage of the supernatant lung due to the retraction of its elastic tissue, and later, when the quantity of serum exceeds about 1·5 litre, by shifting over of the heart and unaffected lung towards the sound side. This shifting may be so extensive that, in a left-sided effusion, the apex of the heart may come to lie under the right mammary papilla. Any pleural effusion that is large enough to embarrass respiration seriously, or has remained unabsorbed for two or three weeks, should be removed by tapping (paracentesis thoracis). The trocar is pushed through the chest-wall into the fluid, in the sixth or seventh intercostal space in the midaxillary line, or in the eighth or ninth space just outside the angle of the scapula. Aspiration is then performed, and as much fluid as possible drawn off: it must be stopped, however, if the patient shows signs of collapse, or if fits of coughing occur and threaten to wound the expanding lung against the sharp end of the trocar. Non-inflammatory or passive effusion into the pleura, called *hydrothorax*, is often seen in the later stages of chronic renal or cardiac disease, and demands treatment on lines similar to the above.

Purulent pleural effusion, or *empyema*, often occurs after such diseases as pneumonia or measles. This condition requires drainage of the cavity, which usually necessitates excision of a portion of a rib. An incision is made down to the seventh or eighth rib in the mid- or posterior axillary line and the periosteum is incised, and separated from the body of the rib, carrying with it the structures in the costal groove. With bone-cutting forceps about 4 cm. or 5 cm. of the rib are separated and removed, and the underlying pleura is incised. The pus having been evacuated, a large drainage tube is inserted into the cavity. The pleura should never be irrigated, as sudden death has followed this proceeding, and great care should be taken to prevent the tube from slipping into the cavity, an occurrence which is far from uncommon.

Pneumothorax, or the presence of gas in the pleural cavity, is a common terminal event in tuberculosis of the lungs; less often it is due to trauma—rupture of the lung, for example, when the chest is crushed, or tearing of the lung-tissue by the sharp projecting end of a broken rib. Air escapes from the lung into the pleural cavity; the elastic tissue of the lung at once contracts, and finally that organ shrinks away to a dark rounded mass the size of a fist, lying close against the vertebral column. The symptoms of pneumothorax are often very severe; cyanosis, intense dyspnœa, great pain on the affected side, and cardiac failure. Their severity is increased by the fact that the blood-vessels of the collapsed lung offer less resistance to the circulation of the blood than do those of the other lung. Not only, therefore, does the sound lung suddenly have to take over the work—the aeration of the blood—normally performed by both lungs, but it has to do so at the moment when the circulation of blood through it is partially short-circuited by the collapsed lung. If the patient survives for a few days, empyema often complicates the pneumothorax, setting up the condition called *pyopneumothorax*. During the last few years a valuable method of treating selected cases of pulmonary tuberculosis by the establishment and maintenance of an artificial pneumothorax on the affected side, causing collapse of the diseased lung, has been employed.

In operations upon the kidney, it must be borne in mind that the pleural cavity usually extends below the level of the medial portion of the last rib, and may therefore be opened in these operations, especially when the last rib is removed in order to give more room.

The Mediastinal Cavity

The **mediastinal cavity**, or space between the right and left pleuræ, extends from the sternum in front to the vertebral column behind (fig. 1041).

FIG. 1041.—A transverse section through the thorax, showing the contents of the middle and posterior mediastinal cavities. Diagrammatic.

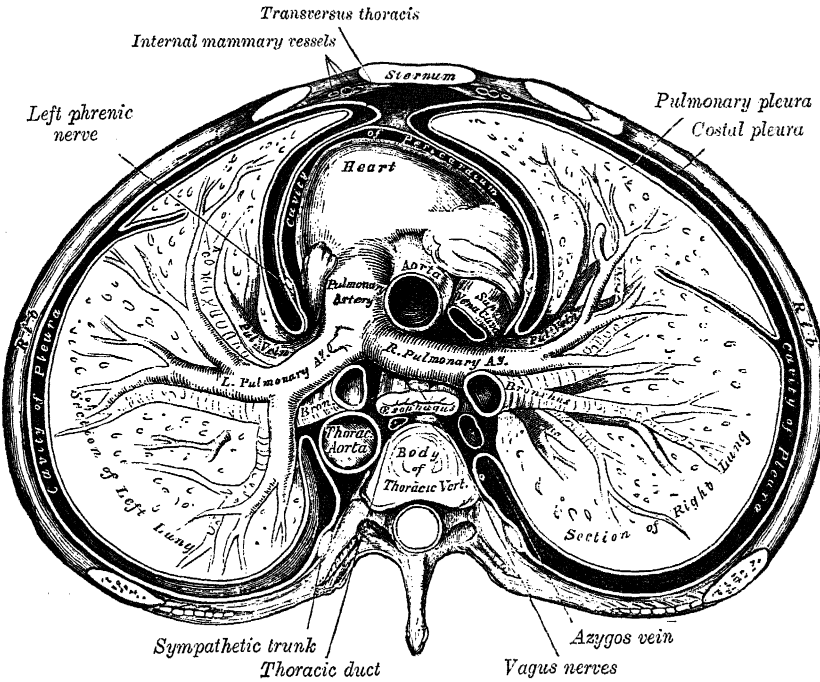
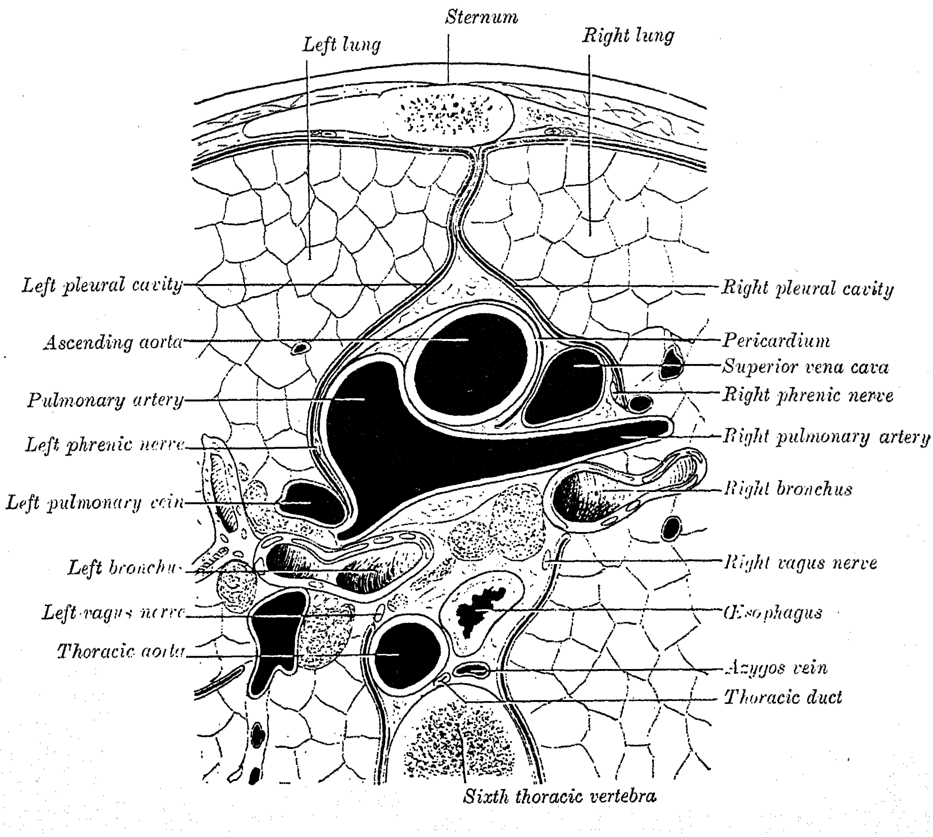


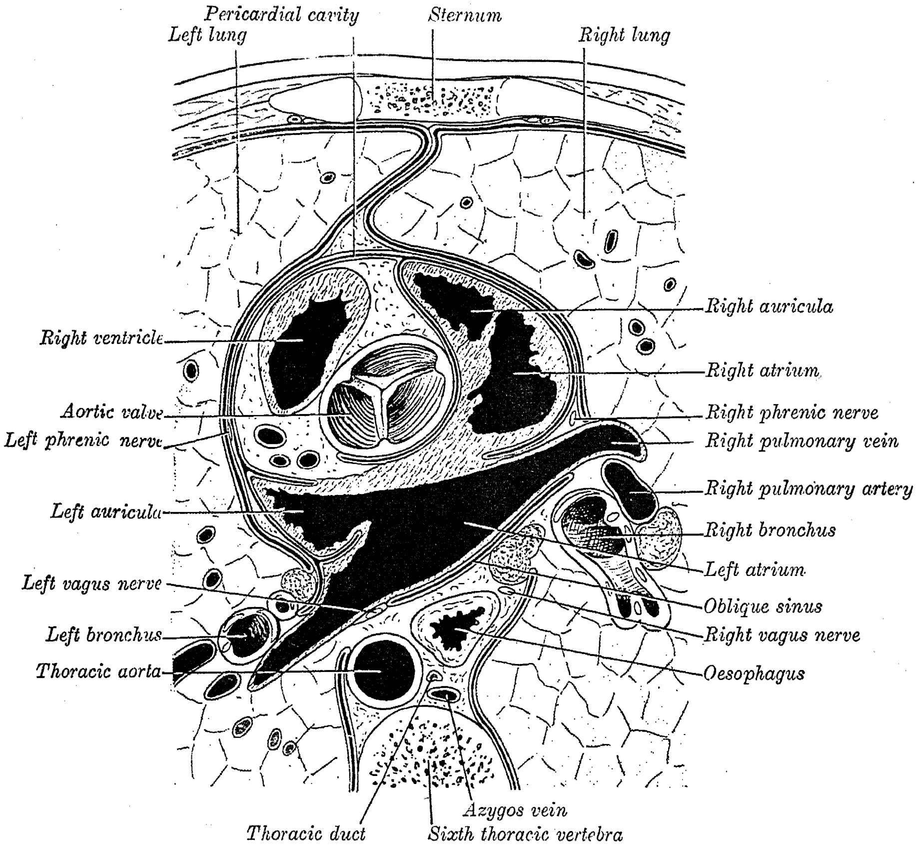
FIG. 1042.—A transverse section through the mediastinal cavity at the level of the upper part of the body of the sixth thoracic vertebra.



It is divided, for purposes of description, into two parts, an *upper*, which is named the superior mediastinal cavity, and a *lower*, which is subdivided into (*a*) the anterior mediastinal cavity, in front of the pericardium, (*b*) the middle mediastinal cavity, containing the pericardium and its contents, and (*c*) the posterior mediastinal cavity, behind the pericardium.

The **superior mediastinal cavity** (figs. 1035, 1036) lies between the manubrium sterni in front, and the upper four thoracic vertebræ behind. It is bounded below by a slightly oblique plane passing from the junction of the

Fig. 1043.—A transverse section through the mediastinal cavity at the level of the lower part of the body of the sixth thoracic vertebra.



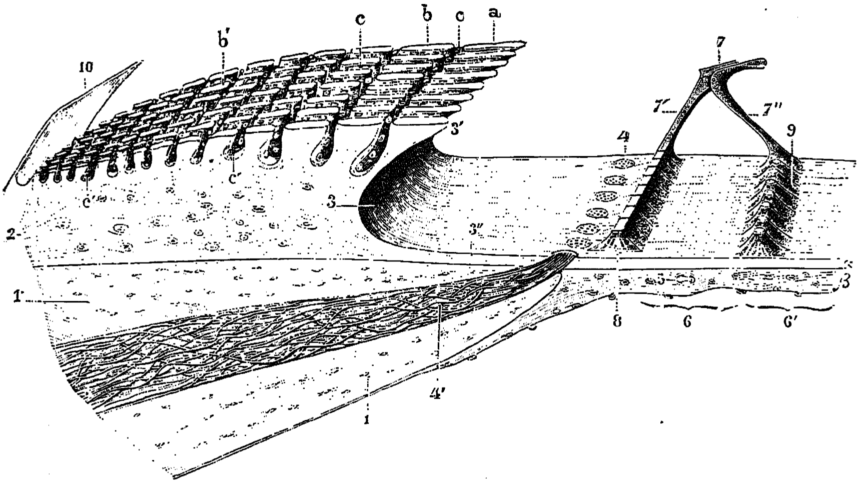
manubrium and body of the sternum to the lower part of the body of the fourth thoracic vertebra, and laterally by the pleuræ; above, by the plane of the thoracic inlet. It contains the origins of the Sternohyoidei and Sternothyreoidei and the lower ends of the Longi colli; the aortic arch; the innominate, left common carotid and left subclavian arteries; the innominate veins and the upper half of the superior vena cava; the left superior intercostal vein; the vagus, cardiac, phrenic, and left recurrent nerves; the trachea œsophagus, and thoracic duct; the remains of the thymus, and some lymph-glands.

The **anterior mediastinal cavity** lies between the sternum in front and the pericardium behind (fig. 1041); it exists only below the level of the fourth costal cartilages, where the left pleura diverges from the mid-sternal line. It contains a quantity of loose areolar tissue, some lymphatic vessels which ascend from the convex surface of the liver, two or three lymph-glands, and a few small mediastinal branches of the internal mammary artery.

Its width increases from 0·21 mm. in the basal turn to 0·36 mm. in the apical turn of the cochlea. The gradual increase in the width of the basilar membrane is accompanied by a corresponding narrowing of the osseous spiral lamina, and a decrease in the size and density of the crista basilaris. The under surface of the membrane is covered by a layer of vascular connective tissue; one of the vessels in this tissue is somewhat larger than the rest, and is named the *vas spirale*; it lies below Corti's tunnel.

The **spiral organ of Corti** (figs. 1000, 1002) is composed of a series of epithelial structures placed upon the zona arcuata or inner part of the basilar membrane. The more central of these structures are two rows of rod-like bodies, the *inner and outer rods or pillars of Corti*. The bases of the rods are supported on the basilar membrane, those of the inner row at some distance from those of the outer; the two rows incline towards each other and, coming

FIG. 1001.—The limbus laminæ spiralis and the basilar membrane. Schematic. (Testut.)



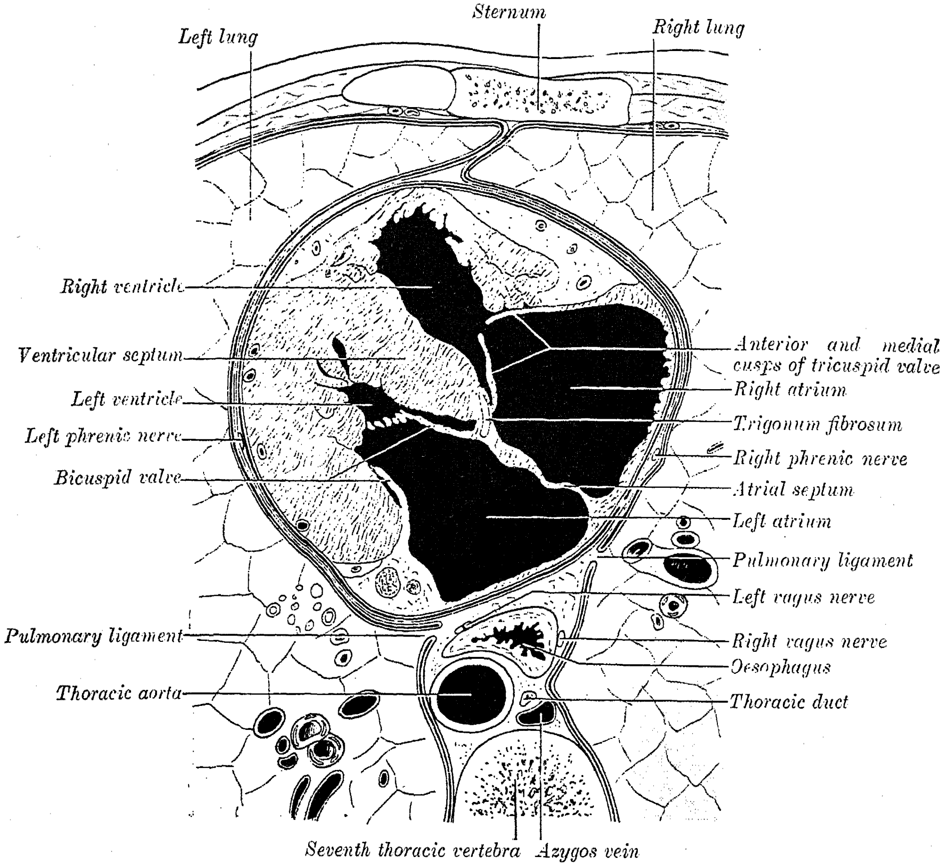
1, 1′. Upper and lower lamellæ of the lamina spiralis ossea. 2. Limbus laminæ spiralis, with *a*, the auditory teeth of the first row; *b*, *b*′, the teeth of the other rows; *c*, *c*′, the grooves between the auditory teeth and the cells which are lodged in them. 3. Sulcus spiralis internus, with 3′, its labium vestibulare, and 3″, its labium tympanicum. 4. Foramina nervosa, giving passage to the nerves from the spiral ganglion of Corti. 5. Vas spirale. 6. Zona arcuata, and 6′, zona pectinata of the basilar membrane, with α, its hyaline layer, β, its connective tissue layer. 7. Summit of the tunnel of Corti, with 7′, its inner rod, and 7″, its outer rod. 8. Bases of the inner rods, from which the cells are removed. 9. Bases of the outer rods. 10. Part of the vestibular membrane.

into contact above, enclose between them and the basilar membrane the *tunnel of Corti* which is triangular in cross section. On the medial side of the inner rods is a single row of hair-cells, and on the lateral side of the outer rods three or four rows of hair-cells, together with certain supporting cells termed the cells of Deiters and of Hensen. The free ends of the outer hair-cells occupy a series of apertures in a net-like membrane, the reticular membrane, and the entire organ is covered by the tectorial membrane.

Rods of Corti.—Each of these consists of a base or foot-plate, an elongated part or body, and an upper end or head; the body of each rod is finely striated, but in the head there is an oval non-striated portion which stains deeply with carmine. Occupying the angles between the rods and the basilar membrane are nucleated cells which partly envelop the rods and extend on to the floor of Corti's tunnel; these may be looked upon as the undifferentiated parts of the cells from which the rods have been formed.

The *inner rods* number nearly 6000, and their bases rest on the basilar membrane close to the tympanic lip of the sulcus spiralis internus. The shaft or body of each is sinuously curved and forms an angle of about 60° with the basilar membrane. The head resembles the proximal end of the ulna, and presents a deep concavity which accommodates a convexity on the head of

Fig. 1045.—A transverse section through the mediastinal cavity at the level of the body of the seventh thoracic vertebra.



Applied Anatomy.—*Primary tumours* of the mediastinum are usually sarcoma or carcinoma arising from the thymus or the mediastinal lymph-glands. Lymphosarcoma, embryoma, and dermoid cysts occur more rarely. These tumours give rise to pain, deformity of the chest, and symptoms of pressure on the nerves, blood-vessels, air-passages, lymphatics, and on the œsophagus, as these various structures pass through the thorax. They may produce physical signs very much like those of an aortic aneurysm, so that diagnosis between the two is often difficult.

Inflammation of the mediastinum due to wounds, or to the spread of inflammation from adjacent parts (e.g. the œsophagus, the pericardium), is sometimes acute, leading to abscess-formation; there is also a chronic form—chronic adhesive mediastinopericarditis —associated with adhesions and inflammation of the pericardium.

The Lungs (Pulmones)

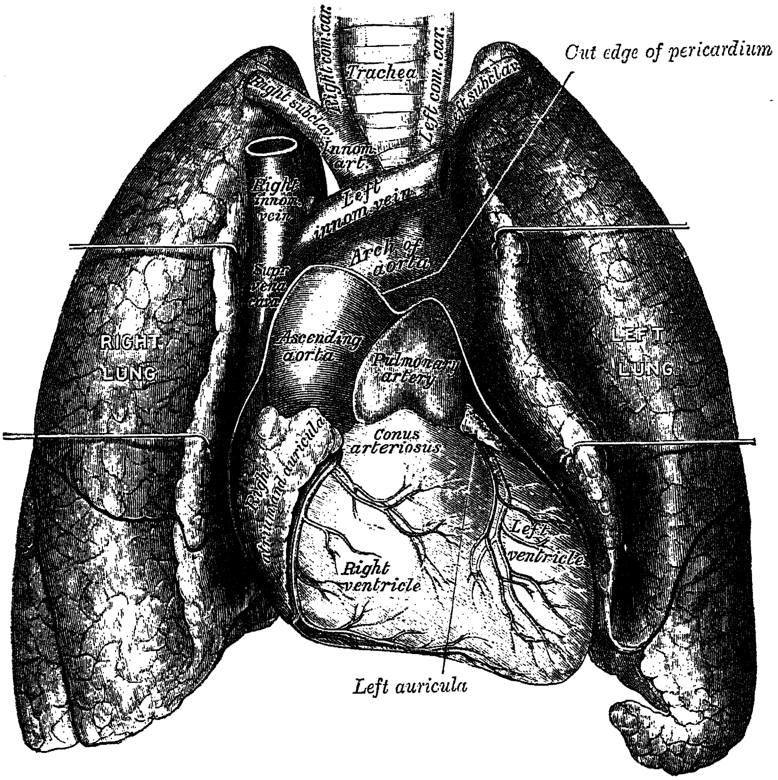
The **lungs** are the essential organs of respiration; they are two in number, placed one on either side within the thorax, and separated from each other by the heart and other contents of the mediastinal cavity (fig. 1046). The substance of the lung is of a light, porous, spongy texture; it floats in water, and crepitates when handled, owing to the presence of air in its alveoli; it is also highly elastic; hence the retracted state of the lungs when they are removed from the closed cavity of the thorax. The surface is smooth, shining, and marked out into numerous polyhedral areas, indicating the lobules of the lung; each of these areas is crossed by numerous lighter lines.

At birth the lungs are pinkish-white in colour; in adult life the colour is a dark slaty-grey, mottled in patches; and as age advances, this mottling

assumes a black colour. The colouring matter consists of granules of a carbonaceous substance deposited in the areolar tissue near the surface of the lung; it increases in quantity as age advances, and is more abundant in males than in females. As a rule, the posterior border of the lung is darker than the anterior.

The right lung usually weighs about 625 gm., the left 567 gm., but much variation is met with according to the amount of blood or serous fluid they contain. The lungs are heavier in the male than in the female; their proportion to the body is, in the former, as 1 to 37, in the latter as 1 to 43.

FIG. 1046.—The heart and lungs. Anterior aspect.



Each lung is conical in shape, and has an apex, a base, three borders, and two surfaces.

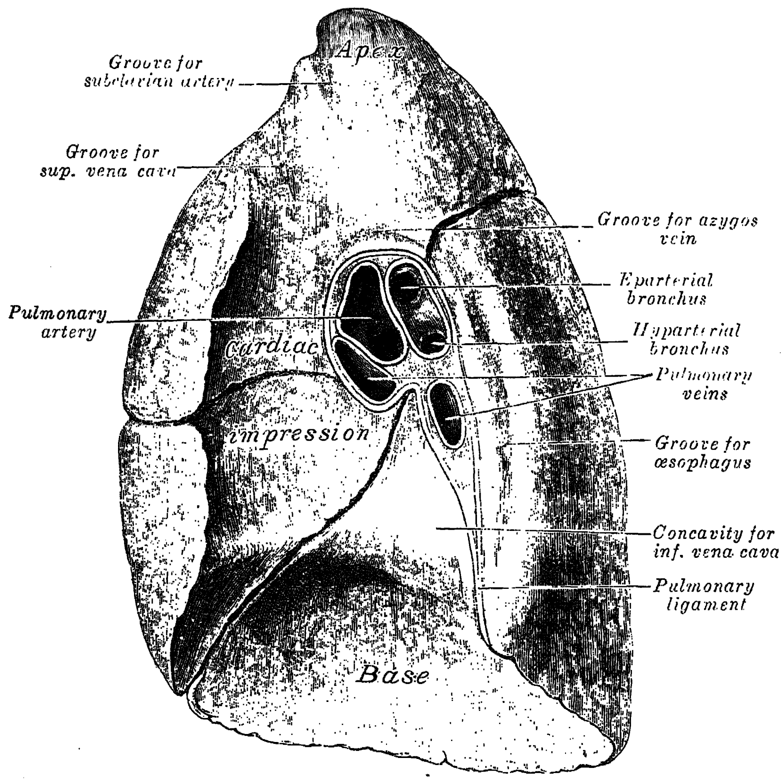
The *apex* is rounded, and extends into the root of the neck, reaching from 3 cm. to 4 cm. above the level of the sternal end of the first rib. A sulcus runs upwards and lateralwards immediately below the apex, and is produced by the subclavian artery.

The *base* is semilunar in shape, and concave; it rests upon the convex surface of the Diaphragm, which separates the right lung from the right lobe of the liver, and the left lung from the left lobe of the liver, the stomach, and the spleen. Since the Diaphragm extends higher on the right than on the left side, the concavity on the base of the right lung is deeper than that on the left. Laterally and behind, the base is bounded by a thin, sharp margin which projects for some distance into the phrenicocostal sinus of the pleura, between the lower ribs and the costal attachment of the Diaphragm.

The *costal surface* is smooth, convex, of considerable extent, and corresponds to the form of the cavity of the chest, which is deeper behind than in front. It is in contact with the costal pleura, and exhibits, in specimens which have been hardened *in situ*, slight grooves corresponding with the overlying ribs.

The *medial surface* is divided into a posterior or *vertebral* part, in contact with the sides of the bodies of the thoracic vertebræ, and an anterior or *mediastinal* part, in contact with the mediastinal pleura. On the mediastinal part is a deep concavity, the *cardiac impression*, which accommodates the pericardium; this concavity is larger and deeper on the left than on the right lung, because the heart projects more to the left than to the right side of the median plane. Above and behind this concavity is a triangular depression named the *hilum*, where the structures which form the root of the lung (p. 1088) enter and leave the viscus. These structures are invested by pleura, which, below the hilum and behind the pericardial impression, forms the pulmonary ligament. On the *right* lung (fig. 1047), immediately above the hilum, is an arched furrow which accommodates the azygos vein; while running upwards,

Fig. 1047.—The mediastinal surface of the right lung.



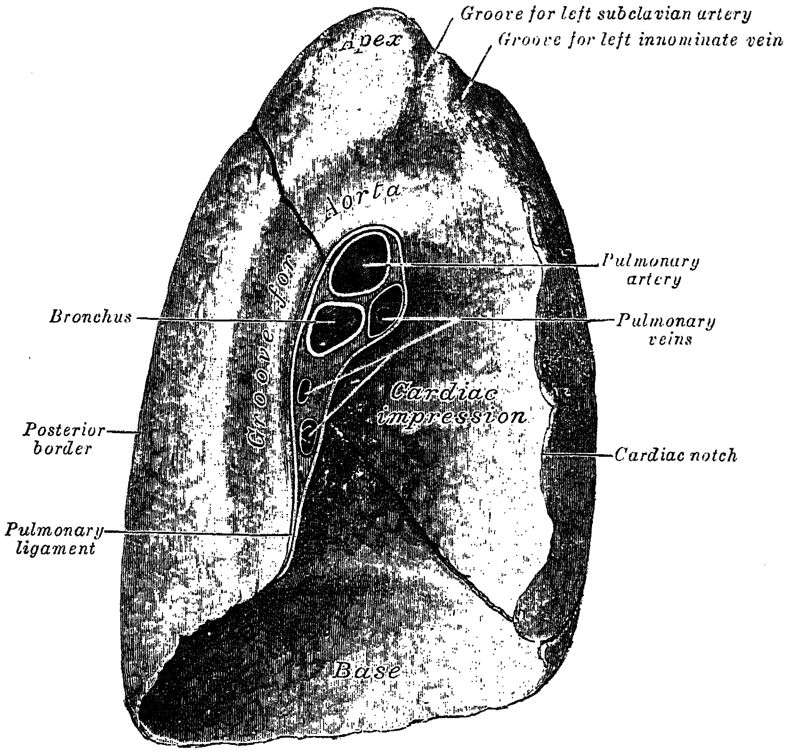
and then arching lateralwards a short distance below the apex, is a wide groove for the superior vena cava and right innominate vein. Behind the hilum and the attachment of the pulmonary ligament is a vertical groove for the œsophagus; this groove becomes less distinct below, owing to the inclination of the lower part of the œsophagus to the left of the middle line. In front and to the right of the lower part of the œsophageal groove is a concavity for the extrapericardiac portion of the thoracic part of the inferior vena cava. On the *left* lung (fig. 1048), immediately above the hilum, is a well-marked curved furrow produced by the aortic arch, and running upwards from this towards the apex is a groove accommodating the left subclavian artery; a slight impression in front of the latter and close to the margin of the lung lodges the left innominate vein. Behind the hilum and pulmonary ligament is a vertical furrow produced by the descending aorta; and in front of this, near the base of the lung, the lower part of the œsophagus causes a shallow impression.

The *inferior border* is thin and sharp where it separates the base from the costal surface, and extends into the phrenicocostal sinus; medially, where it divides the base from the mediastinal surface, it is blunt and rounded. The *posterior border* is broad and rounded, and is received into the deep concavity on either side of the vertebral column. It is much longer than the anterior border, and projects, below, into the phrenicocostal sinus.

The *anterior border* is thin and sharp, and overlaps the front of the pericardium; that of the *right* lung is almost vertical, and projects into the costomediastinal sinus; that of the *left* presents, below, an angular notch, the *cardiac notch*, in which a small part of the pericardium is exposed.

The fissures and lobes of the lungs.—The *left lung* is divided into two lobes (fig. 1048), superior and inferior, by a fissure which extends from

FIG. 1048.—The mediastinal surface of the left lung.



the costal to the mediastinal surface of the lung both above and below the hilum. As seen on the surface, this fissure begins on the mediastinal surface of the lung at the upper and posterior part of the hilum, and runs backwards and upwards to the posterior border, which it crosses at a point about 6 cm. below the apex. It then extends downwards and forwards over the costal surface, and reaches the lower border a little behind its anterior extremity, and its further course can be followed upwards and backwards across the mediastinal surface as far as the lower part of the hilum. The *superior lobe* lies above and in front of this fissure, and includes the apex, the anterior border, a considerable part of the costal surface, and the greater part of the mediastinal surface of the lung. The *inferior lobe*, the larger of the two, is situated below and behind the fissure, and comprises almost the whole of the base, a large portion of the costal surface, and the greater part of the posterior border.

The *right lung* is divided into three lobes, superior, middle, and inferior, by two fissures (fig. 1047). One of these separates the inferior from the middle and superior lobes, and corresponds closely with the fissure in the left lung.

Its direction is, however, more vertical, and it cuts the lower border about 7·5 cm. behind its anterior extremity. The other fissure is short, and separates the superior from the middle lobe. It begins in the previous fissure near the posterior border of the lung, and, running horizontally forwards, cuts the anterior border on a level with the sternal end of the fourth costal cartilage; on the mediastinal surface it may be traced backwards to the hilum. The *middle lobe* of the right lung is small and wedge-shaped, and includes the lower part of the anterior border and the anterior part of the base of the lung.

The right lung, although shorter by 2·5 cm. than the left, in consequence of the Diaphragm rising higher on the right side to accommodate the liver, is broader, owing to the inclination of the heart to the left side; its total capacity and weight are greater than those of the left lung.

The **roots of the lungs.**—A little above the middle of the mediastinal surface of each lung, and nearer its posterior than its anterior border, is the root of the lung, by which the lung is united to the heart and the trachea. The root is formed by the bronchus, the pulmonary artery, the two pulmonary veins, the bronchial arteries and veins, the pulmonary plexuses of nerves, lymphatic vessels, bronchial lymph-glands, and areolar tissue, all of which are enveloped by pleura. The roots of the lungs lie opposite the bodies of the fifth, sixth and seventh thoracic vertebræ. That of the right lung lies behind the superior vena cava and part of the right atrium of the heart, and below the terminal part of the azygos vein. That of the left lung is below the aortic arch and in front of the descending aorta. The following relations are common to the two lung-roots, viz.: in front, the phrenic nerve, the pericardiacophrenic artery and vein, and the anterior pulmonary plexus; behind, the vagus nerve and posterior pulmonary plexus; below, the pulmonary ligament.

The chief structures composing the root of each lung are arranged in a similar manner from before backwards on both sides, viz.: the upper of the two pulmonary veins in front; the pulmonary artery in the middle; and the bronchus behind, with the bronchial vessels on its posterior aspect. Their arrangement differs from above downwards on the two sides; on the right side their position is—eparterial bronchus, pulmonary artery, hyparterial bronchus, pulmonary veins; but on the left side their position is—pulmonary artery, bronchus, pulmonary veins. The lower of the two pulmonary veins is situated below the bronchus, at the apex or lowest part of the hilum (figs. 1047, 1048).

The **divisions of the bronchi.**—Just as the lungs differ from each other in the number of their lobules, so the bronchi differ in their mode of subdivision.

The *right* bronchus gives off, less than 2·5 cm. from the division of the trachea, a branch for the superior lobe; this branch arises above the level of the pulmonary artery, and is therefore named the *eparterial bronchus*. All the other divisions of the main stem come off below the pulmonary artery, and are consequently termed *hyparterial bronchi*. The first of these is distributed to the middle lobe, and the main tube then passes downwards and backwards into the inferior lobe, giving off in its course a series of large ventral and small dorsal branches. The ventral and dorsal branches arise alternately, and there are usually four of each. The branch to the middle lobe is the first of the ventral series.

The *left* bronchus passes below the level of the pulmonary artery before it divides, and hence all its branches are hyparterial; it may therefore be looked upon as equivalent to that portion of the right bronchus which lies on the distal side of its eparterial branch. The first branch of the left bronchus arises about 5 cm. from the bifurcation of the trachea, and is distributed to the superior lobe. The main stem then enters the inferior lobe, where it divides into ventral and dorsal branches similar to those in the right lung. The branch to the superior lobe of the left lung is the first of the ventral series.

Structure.—The lungs are composed of a serous coat, a subserous areolar tissue, and the pulmonary substance.

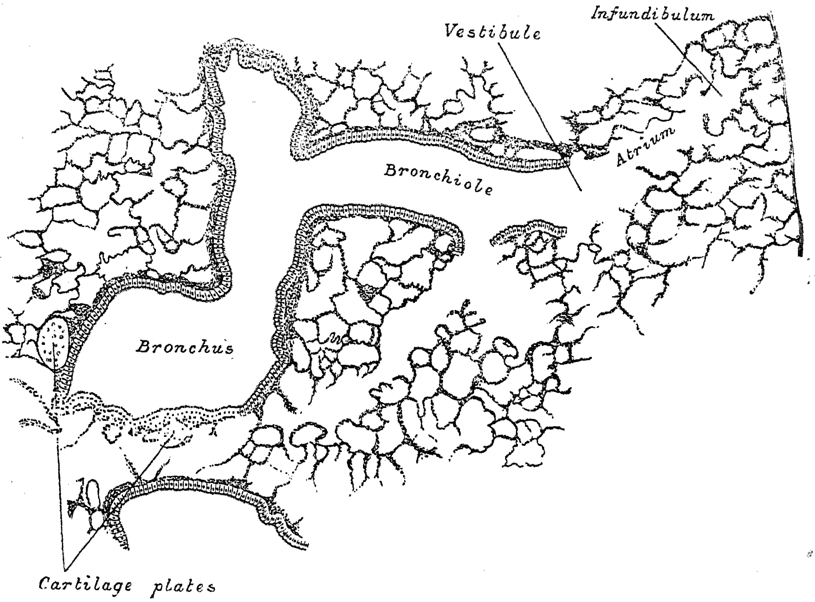
The *serous* coat is the pulmonary pleura (p. 1077); it is thin, transparent, and invests the entire organ as far as the root.

The *subserous areolar tissue* contains a large proportion of elastic fibres; it invests the entire surface of the lung, and extends inwards between the lobules.

The *pulmonary substance* is composed of lobules, which although closely connected by interlobular areolar tissue, are quite distinct from one another, and in the fœtus may be teased asunder without much difficulty. The lobules vary in size; those on the surface are large and of pyramidal form with the bases turned towards the surface; those in the interior are smaller, and of various forms. Each lobule is composed of a lobular bronchiole and its terminal air-cells, and of the ramifications of the pulmonary and bronchial vessels, lymphatics, and nerves; all of these structures being connected together by areolar tissue.

The *intrapulmonary bronchi* divide and subdivide throughout the entire organ, the smallest branches constituting the lobular bronchioles. The *larger branches* consist of: (1) an outer coat of fibrous tissue in which are found at intervals irregular plates of hyaline cartilage, most developed at the points of division; (2) internal to the fibrous coat, a layer of circularly disposed smooth muscular fibres, the *bronchial muscle*; and (3) most internally, the mucous membrane, lined by columnar ciliated epithelium resting on a basement-membrane. The mucous membrane contains numerous elastic fibres running longitudinally, and a certain amount of lymphoid tissue; it is traversed by the ducts

FIG. 1049.—A section through the lung of a cat, showing the termination of a bronchus. × 50.



of mucous glands, the acini of which lie in the fibrous coat. The *lobular bronchioles* are about 0·2 mm. in diameter; they differ from the larger tubes in containing no cartilage and in the fact that the ciliated epithelial cells are cubical in shape.

Each bronchiole ends by opening into a wider space known as the *vestibule*, the point of junction of the two being marked by a circular thickening of the bronchial muscle, and by a transition from the ciliated epithelium of the bronchiole to a layer of flattened non-ciliated cells. The vestibule divides into from three to six passages called *atria*. These are lined by flattened non-ciliated epithelium. From each atrium arise two or more *infundibula*, elongated passages, lined by simple squamous epithelium and beset on all sides by hemispherical alveoli or air-cells (fig. 1049).

The *alveoli* are lined by a layer of simple squamous epithelium, the cells of which are united at their edges by cement-substance. Between the squamous cells are here and there smaller, polygonal, nucleated cells. Outside the epithelial lining is a little delicate connective tissue, containing numerous elastic fibres and a close network of blood-capillaries, and forming a common wall to adjacent alveoli (fig. 1050).

The fœtal lung resembles a gland in that the alveoli have a small lumen and are lined by cubical epithelium (fig. 1051). After the first respiration the alveoli become distended, and the epithelium takes on the characters described above.

Vessels and Nerves.—The *pulmonary artery* conveys the venous blood to the lungs; it divides into branches which accompany the bronchial tubes and end in a dense capillary network in the walls of the infundibula and alveoli. The arteries of neighbouring lobules are independent of one another.

The *pulmonary capillaries* form plexuses which lie immediately beneath the lining epithelium, in the walls and septa of the alveoli and of the infundibula. In the septa

FIG. 1050.—A section through the lung of a kitten. Silver preparation. ×350.

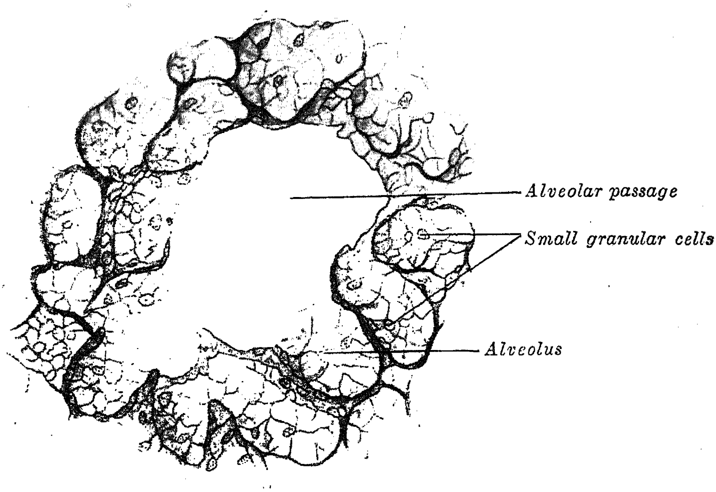
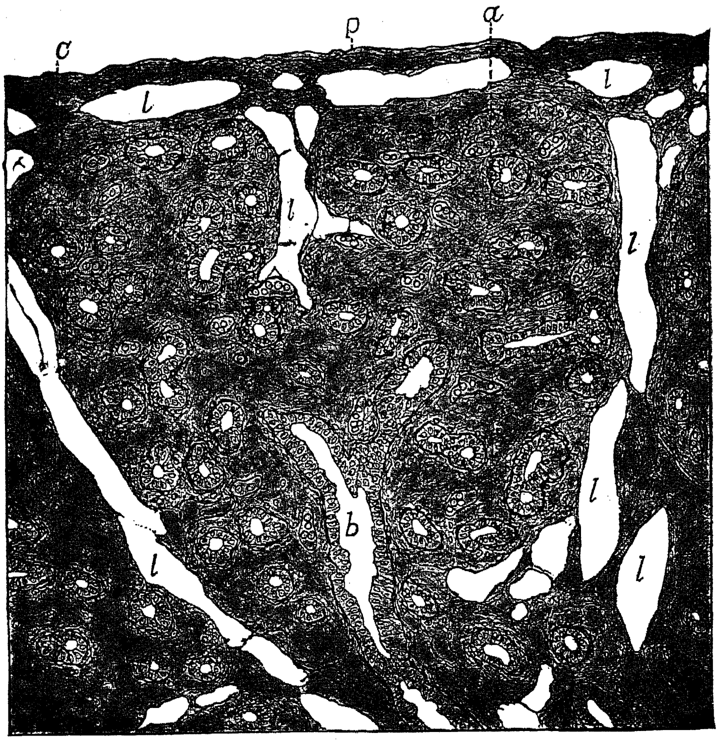


FIG. 1051.—A section through the lung of a pig-embryo 13 cm. long, showing the glandular character of the developing alveoli. ×70. (J. M. Flint.)



a. Interstitial connective tissue. *b.* A bronchial tube. *c.* An alveolus. *l.* Lymphatic clefts. *p.* Pleura.

between the alveoli the capillary network forms a single layer, the meshes of which are smaller than the vessels themselves; their walls are also exceedingly thin.

The *pulmonary veins*, two from each lung, arise from the pulmonary capillaries, the radicles coalescing into larger branches which run through the substance of the lung,

independently of the pulmonary arteries and bronchi. After freely communicating with other branches they form large vessels, which ultimately come into relation with the arteries and bronchial tubes, and accompany them to the hilum of the lung, the artery usually being above, and the vein below, the bronchus. Finally they open into the left atrium of the heart, conveying oxygenated blood to be distributed to all parts of the body by the left ventricle.

The *bronchial arteries* supply blood for the nutrition of the lung; they are derived from the thoracic aorta or from the upper aortic intercostal arteries, and, accompanying the bronchial tubes, are distributed to the bronchial glands and upon the walls of the larger bronchial tubes and pulmonary vessels. Those supplying the bronchial tubes form, in the muscular coat, a capillary plexus from which branches are given off to form a second plexus in the mucous coat; this plexus communicates with branches of the pulmonary artery, and empties itself into the pulmonary veins. Others are distributed in the interlobular areolar tissue, and end partly in the deep, partly in the superficial, bronchial veins. Lastly, some ramify upon the surface of the lung, beneath the pleura, where they form a capillary network.

The *bronchial veins*, usually two on either side, are formed at the root of the lung, and receive superficial and deep veins corresponding with branches of the bronchial arteries; they do not, however, receive all the blood conveyed by the arteries, as some passes into the pulmonary veins. The right bronchial veins end in the azygos vein, the left bronchial veins in the left superior intercostal vein or the accessory hemiazygos vein.

The *lymphatics* of the lungs are described on p. 778.

Nerves.—The lungs are supplied from the anterior and posterior pulmonary plexuses, formed chiefly by branches from the sympathetic and vagus. The filaments from these plexuses accompany the bronchial tubes, supplying efferent fibres to the bronchial muscle and afferent fibres to the bronchial mucous membrane and to the alveoli of the lung. Small ganglia are found upon these nerves.

Applied Anatomy.—The lungs may be wounded or torn in three ways: (1) by compression of the chest, without any injury to the ribs; (2) by a fractured rib penetrating the lung; (3) by stabs, gunshot wounds, etc.

The first form, where the lung is ruptured by external compression, without any fracture of the ribs, is very rare, and usually occurs in young children, and affects the root of the lung, i.e. the most fixed part, and thus, implicating the great vessels, is frequently fatal. It would seem *a priori* a most unusual injury, and its exact mode of causation is difficult to interpret.

In the second variety, when the wound in the lung is produced by the penetration of a broken rib, both the costal pleura and pulmonary pleura must necessarily be injured, and consequently the air taken into the wounded alveoli may find its way through these wounds into the cellular tissue of the parietes of the chest, producing *surgical emphysema*. This it may do without collecting in the pleural cavity; the two layers of the pleura are so intimately in contact that the air passes straight through from the wounded lung into the subcutaneous tissue. Emphysema constitutes therefore the most important sign of injury to the lung in cases of fracture of the ribs. Pneumothorax, or air in the pleural cavity, is much more likely to occur in injuries of the third variety—that is to say, from external wounds, from stabs, gunshot injuries, and such like—in which case air passes either from the wound of the lung or from the external wound into the cavity of the pleura during the respiratory movements. In these cases there is generally no emphysema of the subcutaneous tissue unless the external wound is small and valvular, so that the air is drawn into the wound during inspiration, and then forced into the cellular tissue during expiration because it cannot escape from the external wound. Occasionally in wounds of the parietes of the chest no air finds its way into the cavity of the pleura, because the lung at the time of the accident protrudes through the wound and blocks the opening. This takes place where the wound is large, and constitutes one form of *hernia* of the lung. Another form of hernia of the lung occurs, though very rarely, after wounds of the chest-wall, when the wound has healed and the cicatrix subsequently yields from the pressure of the viscus behind. It forms a globular, elastic, crepitating swelling, which enlarges during expiratory efforts, falls in during inspiration, and disappears on holding the breath.

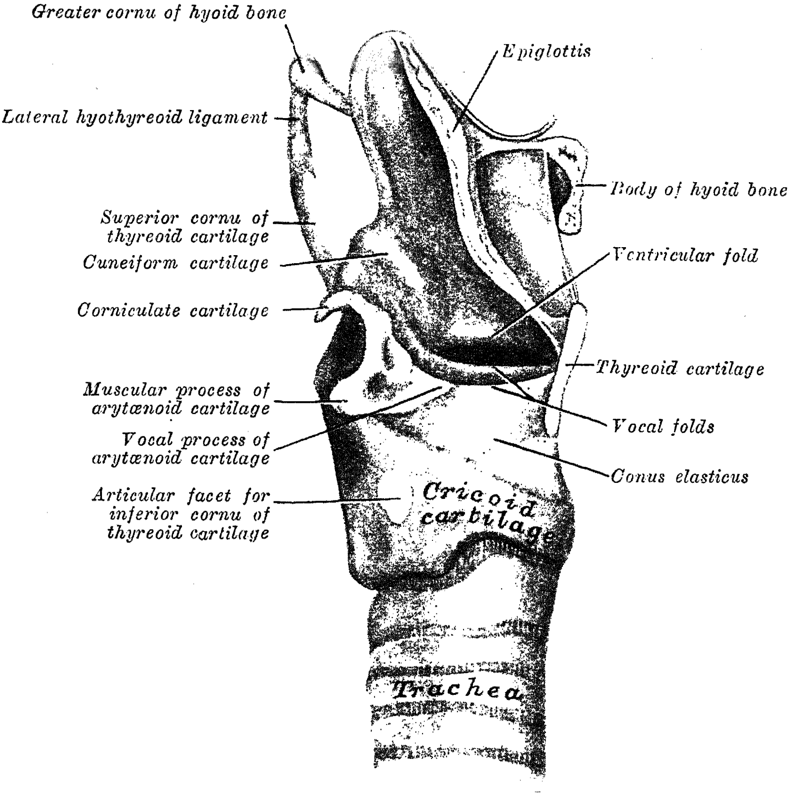
An incision into the lung is occasionally required in cases of abscess the result of pneumonia or the presence of a foreign body, and from an abscess in the liver which has made its way through the Diaphragm into the lung substance, and also in cases of hydatid disease. In these cases there is always risk of hæmorrhage, and it has been recommended that the lung tissue should be penetrated by the actual cautery rather than with the knife. Unless adhesions have formed between the two layers of the pleura, the pleural cavity must necessarily be opened, and there is the further risk of pneumothorax, and possibly of septic infection. It is therefore advisable to suture the lung to the opening in the thoracic wall, and wait for adhesions to form before perforating the lung.

The routine methods of physical examination—inspection, palpation, percussion, and auscultation—are nowhere more important than they are in the diagnosis of disease of the lungs. It is essential, too, that in every case the two sides of the chest should be compared with one another, and that the wide variations that may be met with under

poorly defined; the lower part is a well-marked membrane forming, with its fellow of the opposite side, the conus elasticus, which connects the thyreoid, cricoid, and arytænoid cartilages one to another. The joints between the individual cartilages are also provided with ligaments, already described.

The *conus elasticus* (cricothyreoid membrane) (fig. 1024) is composed mainly of yellow elastic tissue. It consists of an anterior and two lateral parts. The *anterior* part or *middle cricothyreoid ligament* is thick and strong, narrow above and broad below. It connects the front parts of the contiguous margins of the thyreoid and cricoid cartilages. It is overlapped on either side by the Cricothyreoideus, but between these muscles is subcutaneous; its upper part is

FIG. 1024.—A dissection to show the right half of the conus elasticus. The right lamina of the thyreoid cartilage and the subjacent muscles have been removed.



crossed by a small arterial arch, formed by the junction of the two cricothyreoid arteries; branches of this arch pierce the ligament. The *lateral* parts of the conus elasticus are thinner; they are lined with the mucous membrane of the larynx, and are covered by the Cricoarytænoidei laterales and Thyreoarytænoidei. They extend upwards and medialwards from the inner edge of the superior border of the cricoid cartilage, and end above in free, slightly thickened edges which form the vocal ligaments; these ligaments stretch from the vocal processes of the arytænoid cartilages to the angle of the thyreoid cartilage about midway between the upper and lower borders of the cartilage.

Cavum laryngis (figs. 1025, 1026).—The *cavity of the larynx* extends from the laryngeal entrance, by which it communicates with the pharynx, to the level of the lower border of the cricoid cartilage, where it is continuous with the cavity of the trachea. It is divided into three parts by an upper and a lower pair of folds of mucous membrane which project from the sides of the cavity into its interior. The upper folds are named the *ventricular folds* (false vocal cords), and the fissure between them is called the *rima vestibuli*. The

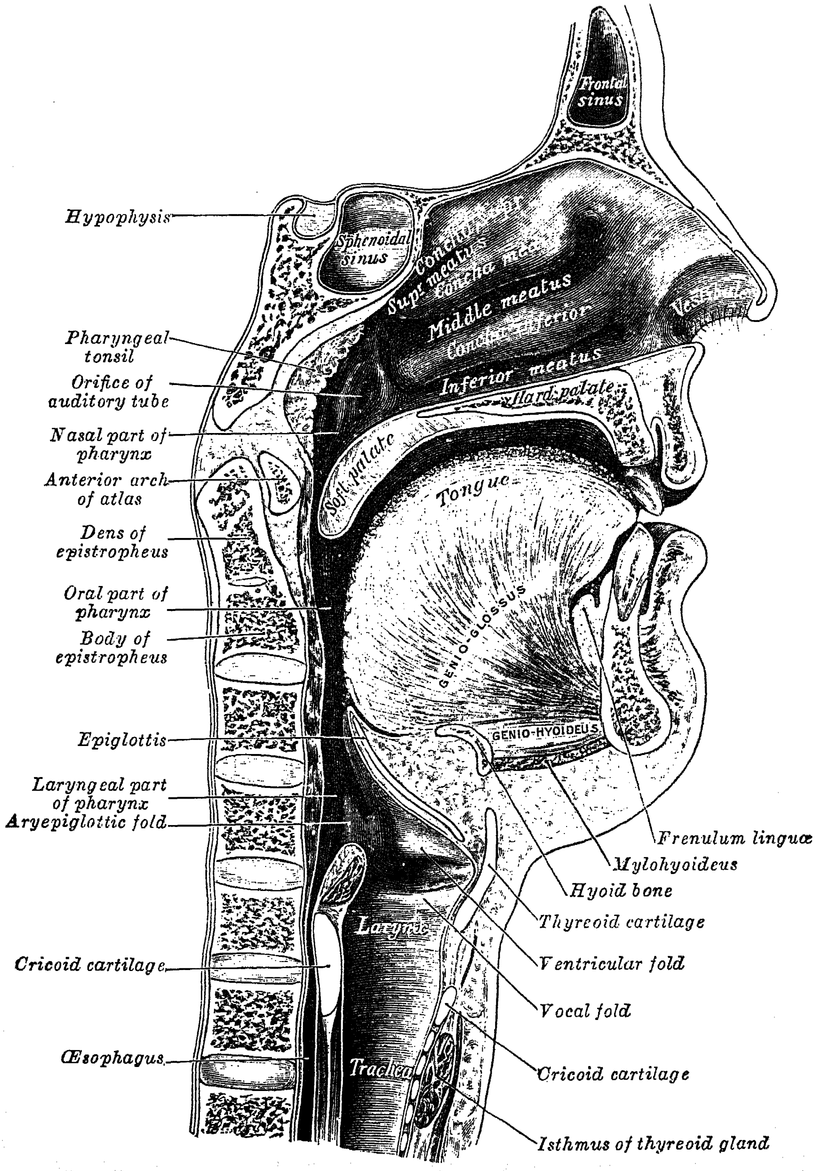
ends in the *large intestine*, which is made up of the *cæcum*, the *colon*, the *rectum*, and the *anal canal*, the last ending on the surface of the body at the *anus*.

The **accessory organs** are the *teeth*, for purposes of mastication; the three pairs of *salivary glands*—the *parotid*, *submaxillary* and *sublingual*—the secretion from which mixes with the food in the mouth and acts chemically on one of its constituents; the *liver* and the *pancreas*, two large glands in the abdomen, the secretions of which, in addition to that of numerous minute glands in the walls of the alimentary canal, take part in the process of digestion.

The Mouth Cavity (Cavum oris)

The **cavity of the mouth** is placed at the commencement of the digestive tube (fig. 1052); it consists of an outer, smaller portion, the vestibule, and an inner, larger part, the mouth cavity proper.

Fig. 1052.—A sagittal section through the nose, mouth, pharynx, and larynx.



The *vestibule of the mouth* is a slit-like space, bounded externally by the lips and cheeks; internally by the gums and teeth. It communicates with the surface of the body by the *orifice of the mouth* (rima oris). Above and below, it is limited by the reflection of the mucous membrane from the lips and cheeks to the gums covering the upper and lower alveolar arches. The ducts of the parotid salivary glands open into it, and it communicates, when the jaws are closed, with the mouth cavity proper by an aperture on either side behind the wisdom teeth, and by narrow clefts between opposing teeth.

The *mouth cavity proper* (fig. 1074) is bounded laterally and in front by the alveolar arches with their contained teeth; behind, it communicates with the pharynx by a constricted aperture termed the *isthmus faucium*. Its roof consists of the hard palate and soft palate, while the greater part of the floor is formed by the tongue, the remainder by the reflection of the mucous membrane from the sides and under surface of the tongue to the gum on the inner surface of the mandible. The ducts of the submaxillary and sublingual salivary glands open into it.

The *mucous membrane* lining the mouth is continuous with the skin at the free margins of the lips, and with the mucous lining of the pharynx at the isthmus faucium; it is of a rose pink tinge during life, and very thick where it overlies the hard parts bounding the cavity. It is covered with stratified squamous epithelium.

The *lymphatics* of the mouth are described on p. 755.

The **lips** (labia oris), the two fleshy folds which surround the rima or orifice of the mouth, are formed externally of skin and internally of mucous membrane, between which are found the Orbicularis oris muscle, the labial vessels, some nerves, areolar tissue, and fat, and numerous small labial glands. The junction of the upper with the lower lip forms, on either side, the *labial commissure*, which bounds the *angle of the mouth*. On the middle part of the outer surface of the upper lip is a shallow vertical groove named the *philtrum* which descends from the columna nasi; it ends below in a slight prominence and is limited on either side by a ridge. The inner surface of each lip is connected in the middle line to the corresponding gum by a fold of mucous membrane, the *frenulum*—that of the upper lip being the larger.

The *labial glands* are situated between the mucous membrane and the Orbicularis oris, round the orifice of the mouth. They are about the size of small peas; their ducts open into the vestibule. In structure they resemble the salivary glands.

The **cheeks** (buccæ) form a large part of the sides of the face, and are continuous in front with the lips, the junction being indicated on either side by a groove, the *nasolabial sulcus*, which runs downwards and lateralwards from the side of the nose to the angle of the mouth. The cheeks are composed externally of skin, and internally of mucous membrane; between these are a muscular stratum, and a large quantity of fat, together with areolar tissue, vessels, nerves, and buccal glands.

The *mucous membrane* lining the cheek is reflected above and below upon the gums, and is continuous behind with the lining membrane of the soft palate. Opposite the second upper molar tooth is a papilla, on the summit of which the parotid duct opens. The principal muscle of the cheek is the Buccinator; but others enter into its formation, viz. the Zygomaticus, Risorius, and Platysma.

The *buccal glands* are placed between the mucous membrane and the Buccinator muscle; their structure is similar to that of the labial glands. Four or five, larger than the rest, and placed between the Masseter and Buccinator muscles around the distal extremity of the parotid duct, are called *molar glands*; their ducts open in the mouth opposite the last molar tooth.

The *lymphatics* of the cheeks and lips are described on p. 755.

The **gums** (gingivæ) are composed of dense fibrous tissue, closely connected to the periosteum of the alveolar processes of the mandible and maxillæ, and are covered by smooth and vascular mucous membrane. Around the necks of the teeth this membrane presents numerous fine papillæ, and is reflected into the alveoli, where it is continuous with the periosteal membrane lining these cavities.

Applied Anatomy.—The gums are occasionally the seat of considerable hypertrophy, forming a lobulated vascular fold growing up in front of and behind the teeth, so as almost

to bury them. They may also become swollen and congested, bleeding freely, and often becoming ulcerated. The condition is known as *spongy gums*, and may occur in scurvy, in stomatitis and dyspepsia, in ill-fed tuberculous children, and from the administration of mercury; the gums are very tender, mastication is painful, and there is often considerable fœtor. The dental margin of the gum presents a finely stippled blue or blue-black line in cases of *lead poisoning*, due to the local deposit of black lead sulphide. In cases of *bismuth poisoning*, such as may occur after the too generous use of insoluble bismuth salts in the surgical treatment of gunshot wounds, a very similar but more diffuse blue line due to the local deposit of black sulphide of bismuth may appear, together with patches of minute black dots about other parts of the mucous membrane of the mouth. The collection of tartar, which consists of the secretion from the gums mixed with fragments of food and salivary salts, may give rise to a condition known as *pyorrhœa alveolaris*, which is an inflammatory condition of the gums, followed by the gradual absorption of the alveolus and the falling out of the teeth. Fibrous tumours (epulis), myeloid growths, and epitheliomata are met with in the gums.

The **palate** forms the roof of the mouth: it consists of two portions, the hard palate in front, the soft palate behind.

The **hard palate** (palatum durum) (fig. 1060) is formed by the palatine processes of the maxillæ and the horizontal parts of the palatine bones; it is bounded in front and at the sides by the alveolar arches and gums; behind, it is continuous with the soft palate. It is covered by a dense tissue, formed by the periosteum and mucous membrane, which are intimately connected. Along the middle line is a linear raphe which ends anteriorly in a small papilla underlying the incisive canal. On either side and in front of the raphe the mucous membrane is thick, pale in colour, and corrugated; behind, it is thin, smooth, and of a redder colour: it is covered with stratified squamous epithelium, and furnished with numerous palatine glands which lie between the mucous membrane and the periosteum.

The **soft palate** (palatum molle) (fig. 1074) is a movable fold, suspended from the posterior border of the hard palate, and forming an incomplete septum between the mouth and pharynx. It consists of a fold of mucous membrane enclosing an aponeurosis, muscular fibres, vessels, nerves, adenoid tissue, and mucous glands. When occupying its usual position (i.e. relaxed and pendent) its anterior surface is concave, and marked by a median raphe. Its posterior surface is convex, and continuous with the floor of the nasal cavities. Its superior border is attached to the posterior margin of the hard palate, and its sides are blended with the pharynx. Its inferior border is free. The lower portion of the soft palate hangs like a curtain between the mouth and the pharynx, and is termed the *palatine velum*.

Hanging from the middle of its lower border is a small, conical process, the *palatine uvula*; and arching lateralwards and downwards from the base of the uvula on either side are two curved folds of mucous membrane, containing muscular fibres, called the *arches* or *pillars of the fauces* (p. 1118).

The *mucous membrane of the soft palate* is thin, and covered with stratified squamous epithelium, excepting near the pharyngeal ostium of the auditory tube, where it is columnar and ciliated. Beneath the mucous membrane on the oral surface of the soft palate is a considerable amount of adenoid tissue. The palatine glands form a continuous layer on its posterior surface and round the uvula.

Vessels and Nerves.—The *arteries* supplying the palate are the ascending palatine branch of the external maxillary artery, the descending palatine branch of the internal maxillary artery, and the palatine branch of the ascending pharyngeal artery. The *veins* end chiefly in the pterygoid and tonsillar plexuses. The *lymphatic vessels* pass to the deep cervical lymph-glands. The *sensory nerves* are derived from the palatine, nasopalatine and glossopharyngeal nerves.

Applied Anatomy.—The occurrence of a congenital cleft in the palate has been already referred to as a defect in development (p. 82). After the operation for the closure of a cleft in the palate, the palatine muscles, especially the Tensor and Levator veli palatini, have a tendency to retard the healing process by active traction upon the line of suture. To obviate this, it is necessary to divide them. This is best done by making longitudinal incisions, on either side, parallel to the cleft and just medial to the pterygoid hamulus, in such a position as to avoid the descending palatine artery. Acquired perforations of the palate are almost invariably the result of the breaking down of syphilitic gummata. The ensuing ulceration may continue until practically the whole palate, both hard and soft, has been destroyed. Tumours of the palate, both innocent and malignant, are occasionally seen.

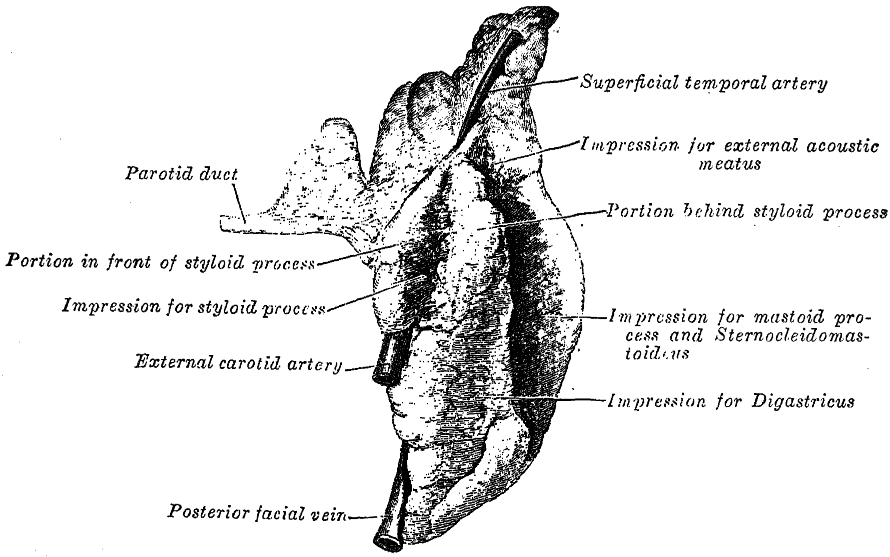
Paralysis of the soft palate often occurs after diphtheria. It gives rise to a change in the voice, which becomes nasal, and to the regurgitation of fluids down the nose when their swallowing is attempted. On inspection, the palate is seen to hang flaccid and motionless when phonation or deglutition is attempted; it is also anæsthetic.

The Salivary Glands (fig. 1055)

Three pairs of salivary glands pour their secretion into the mouth: they are named the parotid, the submaxillary, and the sublingual glands.

The **parotid gland** (figs. 1053, 1054), the largest of the three, has an average weight of about 25 gm. It lies upon the side of the face, immediately below and in front of the external ear. The main portion of the gland is superficial, somewhat flattened and quadrilateral in form, and is placed between

Fig. 1053.—The right parotid gland. Posterior aspect.



the ramus of the mandible in front and the mastoid process and Sternocleidomastoideus behind, overlapping, however, both boundaries. Above, it is broad and reaches nearly to the zygomatic arch; below, it tapers somewhat to about the level of a line joining the tip of the mastoid process to the angle of the mandible. The remainder of the gland (retromandibular process) is irregularly wedge-shaped and extends deeply inwards towards the pharyngeal wall.

The gland is enclosed within a capsule continuous with the fascia colli (deep cervical fascia); the part covering the superficial surface of the gland is dense, closely adherent to the gland, and attached to the zygomatic arch; a portion of the fascia, attached to the styloid process and the angle of the mandible, is thickened to form the stylomandibular ligament, which intervenes between the parotid and submaxillary glands.

The *anterior surface* of the gland is grooved, being moulded on the posterior border of the ramus of the mandible, and on the posterior borders of the Pterygoideus internus and Masseter. The inner lip of the groove extends forwards for a short distance on the deep surface of the Pterygoideus internus; the outer lip extends for some distance over the superficial surface of the Masseter, and a small portion of it immediately below the zygomatic arch is usually more or less detached, and is named the *accessory part* of the gland.

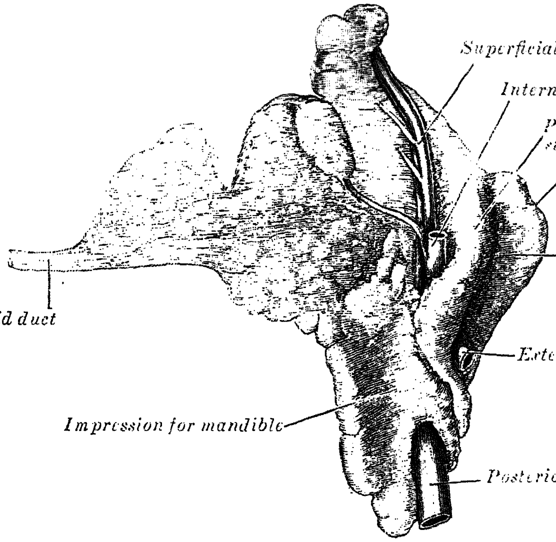
The *posterior surface* is grooved longitudinally and abuts against the external acoustic meatus, the mastoid process, and the anterior border of the Sternocleidomastoideus.

The *superficial surface*, slightly lobulated, is covered by the skin, the superficial fascia containing the facial branches of the great auricular nerve and some small lymph-glands, and by the fascia which forms the capsule of the gland.

The *deep surface* extends inwards by means of two processes, one of which lies on the Digastricus, styloid process, and the styloid group of muscles, and projects under the mastoid process and Sternocleidomastoideus; the other is situated in front of the styloid process, and sometimes passes into the posterior part of the mandibular fossa behind the mandibular joint. The deep surface is in contact with the internal carotid artery and the internal jugular vein.

Structures within the gland.—The external carotid artery lies at first on the deep surface, and then in the substance of the gland. The artery gives off its posterior auricular branch, which emerges from the gland behind; the artery then divides into the internal maxillary and superficial temporal arteries;

FIG. 1054.—The right parotid gland. Medial aspect.



the former runs forwards deep to the neck of the mandible; the latter runs upwards across the zygomatic arch and gives off its transverse facial branch, which emerges from the front of the gland. Superficial to the arteries are the superficial temporal and internal maxillary veins, uniting to form the posterior facial vein; in the lower part of the gland this vein splits into an anterior and a posterior division. The anterior division emerges from the gland and unites with the anterior facial vein to form the common facial vein; the posterior unites in the gland with the posterior auricular vein to form the external jugular vein. On a still more superficial plane is the facial nerve, the branches of which emerge from the borders of the gland. Branches of the great auricular nerve pierce the gland to join the facial nerve, and the cutaneous part of the auriculotemporal nerve issues from the upper part of the gland.

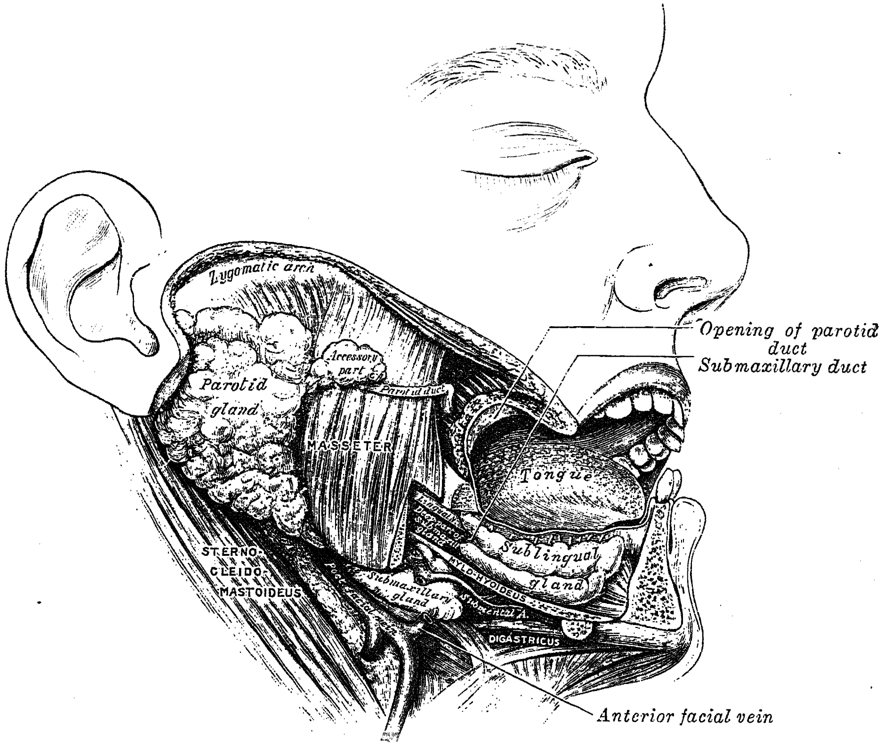
The **parotid duct** (Stensen's duct) (fig. 1055) is about 5 cm. long. It begins by numerous branches from the anterior part of the gland, crosses the Masseter, and at the anterior border of this muscle turns inwards nearly at a right angle, passes through the corpus adiposum of the cheek and pierces the Buccinator; it then runs for a short distance obliquely forwards between the Buccinator and mucous membrane of the mouth, and opens upon a small papilla on the oral surface of the cheek opposite the second upper molar tooth. While crossing the Masseter it receives the duct of the accessory portion; in this position it lies between the branches of the facial nerve; the accessory part of the gland and the transverse facial artery are above it.

Structure.—The wall of the parotid duct is of considerable thickness, and consists of a thick external fibrous coat which contains unstriped muscular fibres, and an internal mucous coat which is lined with short columnar epithelium. Its canal is about the size of a crow-quill, but at its orifice on the oral surface of the cheek its lumen is greatly reduced in size.

Vessels and Nerves.—The *arteries* supplying the parotid gland are derived from the external carotid artery, and from the branches given off by that vessel in or near the gland. The *veins* empty themselves into the external jugular vein, through some of its tributaries. The *lymphatics* end in the superficial and deep cervical lymph-glands, passing in their course through two or three lymph-glands, on the surface and in the substance of the parotid gland. The *nerves* are derived from the facial, auriculotemporal and great auricular nerves and from the plexus of the sympathetic on the external carotid artery. It is probable that the branch from the auriculotemporal nerve is derived from the glossopharyngeal nerve through the otic ganglion; at all events, in some of the lower animals this has been proved experimentally to be so.

The **submaxillary gland** (fig. 1055) is irregular in form and about the size of a walnut. It consists of a larger, superficial part and a smaller deep part, which are continuous with one another around the posterior border of the Mylohyoideus.

FIG. 1055.—A dissection showing the salivary glands of the right side.



The *superficial part* of the submaxillary gland is situated in the submaxillary triangle, reaching forwards to the anterior belly of the Digastricus and backwards to the stylomandibular ligament, which intervenes between the submaxillary and parotid glands. Above, it extends under cover of the body of the mandible; below, it usually overlaps the intermediate tendon of the Digastricus and the insertion of the Stylohyoideus. It has three surfaces, an inferior, a lateral, and a medial.

The *inferior surface* is covered by the skin, Platysma, and deep cervical fascia. It is crossed by the anterior facial vein, and by some filaments of the facial nerve; in contact with it near the mandible are the submaxillary lymph-glands.

The *lateral surface* is in relation with the submaxillary depression on the inner surface of the body of the mandible, and with the lower part of the inner surface the Pterygoideus internus.

The *medial surface* is in relation with the Mylohyoideus, Hyoglossus, Styloglossus, Stylohyoideus, and posterior belly of the Digastricus; between it and the Mylohyoideus are the mylohyoid nerve and vessels.

The external maxillary artery is embedded in a groove in the posterior border of the gland.

The *deep part* of the submaxillary gland extends forwards as far as the posterior end of the sublingual gland, and lies between the Mylohyoideus below and externally and the Hyoglossus and Styloglossus internally; above it are the lingual nerve and submaxillary ganglion; below it, the hypoglossal nerve and its vena comitans.

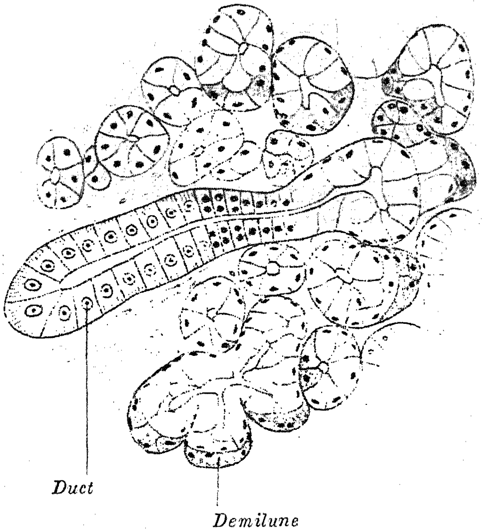
The **submaxillary duct** (Wharton's duct) is about 5 cm. long, and its wall is much thinner than that of the parotid duct. It begins by numerous branches in the superficial part of the gland, and runs with the deep part of the gland forwards between the Mylohyoideus and the Hyoglossus; it then passes between the sublingual gland and the Genioglossus, and opens by a narrow orifice on the summit of a small papilla, at the side of the frenulum linguæ (fig. 1073). On the Hyoglossus it lies between the lingual and hypoglossal nerves, but at the anterior border of the muscle it is crossed laterally by the lingual nerve; the terminal branches of the lingual nerve ascend on its medial side.

Vessels and Nerves.—The *arteries* supplying the submaxillary gland are branches of the external maxillary and lingual arteries. Its *veins* follow the course of the arteries. The *nerves* are derived from the submaxillary ganglion, through which it receives filaments from the chorda tympani of the facial nerve, the lingual branch of the mandibular nerve and the sympathetic.

In the dog and cat the submaxillary gland receives its nerve-supply through Langley's ganglion (p. 1100).

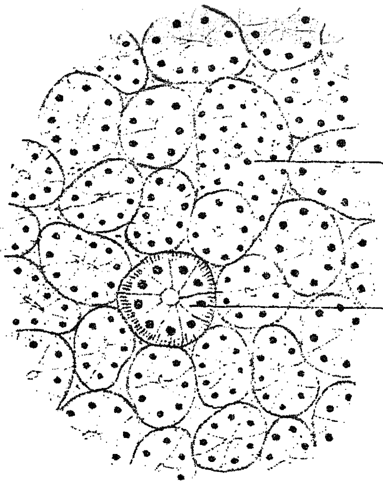
The **sublingual gland** (fig. 1055) is the smallest of the three salivary glands. It is situated beneath the mucous membrane of the floor of the mouth, at the side of the frenulum linguæ, in contact with the sublingual depression on the inner surface of the mandible, close to the symphysis. It is narrow, flattened, shaped somewhat like an almond, and weighs between 3 and 4 gms. It is in relation, *above*, with the mucous membrane of the mouth which it raises in the form of a crest, named the *plica sublingualis*; *below*, with the Mylohyoideus; *in front*, with its fellow of the opposite side; *behind*, with the deep part of the submaxillary gland; *laterally*, with the mandible; and *medially*, with the Genioglossus, from which it is separated by the lingual nerve and the submaxillary duct. Its excretory ducts are from eight to twenty in number. Of the *smaller sublingual ducts* (ducts of Rivinus), some join the submaxillary duct; others open separately into the mouth, on the plica sublingualis. One or more join to form the *larger sublingual duct* (duct of Bartholin), which opens with or near to the submaxillary duct.

FIG. 1056.—A section through the submaxillary gland of a kitten. Duct semidiagrammatic. × 200.



Vessels and Nerves.—The sublingual gland is supplied with blood by the sublingual and submental arteries. Its nerves are derived from the lingual and chorda tympani nerves, and from the sympathetic.

FIG. 1057.—A section through the parotid gland of a cat. ×200.



In the dog and cat the sublingual gland receives its nerve-supply through the submaxillary ganglion.

Structure of the salivary glands.—The salivary glands are compound racemose glands, consisting of numerous lobes, which are made up of lobules, connected together by dense areolar tissue, vessels and ducts. Each lobule consists of the ramification of a single duct, the branches ending in dilated ends or alveoli on which the capillaries are distributed. The alveoli are enclosed by a basement-membrane, which is continuous with the membrana propria of the duct and consists of a network of branched and flattened nucleated cells.

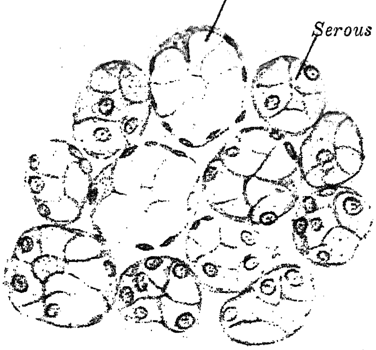
The alveoli of the salivary glands are of two kinds, serous and mucous, which differ in the nature of their secretion and in the appearance of their cells. (1) The mucous alveoli secrete a viscid fluid, which contains mucin; (2) the serous secrete a thinner and more watery fluid. The sublingual gland consists of mucous, and the parotid gland of serous, alveoli. The submaxillary gland contains both mucous and serous alveoli (fig. 1058).

The cells in the *mucous alveoli* are columnar in shape (fig. 1056), and in the fresh condition contain large granules of mucinogen. In hardened preparations a delicate protoplasmic network is seen, and the cells are clear and transparent. The nucleus is usually situated near the basement-membrane, and is flattened.

In some alveoli peculiar crescentic bodies are seen between the cells and the basement-membrane. They are termed the *crescents of Gianuzzi*, or the *demilunes of Heidenhain* (fig. 1056), and are composed of polyhedral granular cells. Fine canaliculi pass between the mucus-secreting cells to reach the demilunes and penetrate their cells.

In the *serous alveoli* the cells almost completely fill the cavity in the resting condition of the gland, so that the lumen is barely perceptible; they contain granules imbedded in a closely reticulated protoplasm (fig. 1057). The cells are more cubical than those of mucous alveoli; the nucleus of each is spherical and placed near the centre of the cell, and the granules are smaller.

FIG. 1058.—A section through a human submaxillary gland. Stained with hæmatoxylin and eosin. ×300.



Both mucous and serous cells vary in appearance according to whether the gland is in a resting condition or has been recently active. In the former case the cells are large and contain many granules; in the latter case the cells are shrunken and contain few granules, chiefly collected at the inner ends of the cells. The granules are best seen in fresh preparations.

The ducts are lined at their origins by pavement epithelium, but as they enlarge, the epithelial cells change to the columnar type, and the part of the cell next the basement-membrane is finely striated.

The lobules of the salivary glands are richly supplied with blood-vessels, which form a dense network in the inter-alveolar spaces. Fine plexuses of nerves are also found in the interlobular tissue. The nerve-fibrils pierce the basement-membrane of the alveoli, and end in branched varicose filaments between the secreting cells. In the hilum of the submaxillary gland there is in some animals a collection of nerve cells termed *Langley's ganglion*.

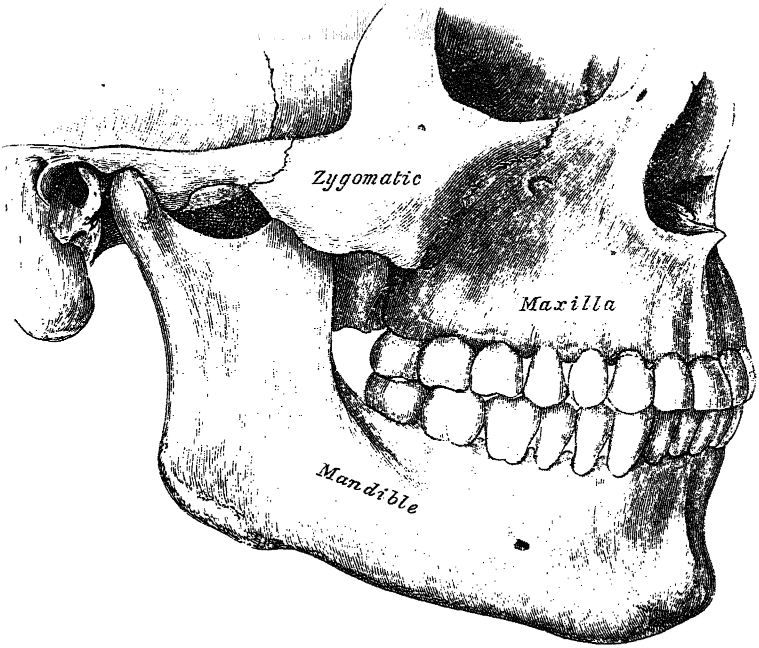
Accessory glands.—Besides the salivary glands proper, numerous other glands are found in the mouth. Some of these occur in the tongue (p. 1117); others lie around and in the palatine tonsil between its crypts, and large numbers are present in the soft palate, the lips and cheeks. These glands are of the same structure as the larger salivary glands, and are of the mucous or mixed type.

Applied Anatomy.—The parotid glands, and much less often the other salivary glands, are liable to an acute infectious inflammation, known in the case of the parotid as *mumps*. The affected glands swell up, becoming tense, tender, and painful; much pain is felt when swallowing or mastication is attempted, and salivation may or may not occur. The inflammation goes down after a few days; suppuration in the affected glands is very rare.

THE TEETH (DENTES) (figs. 1059 to 1062)

Man is provided with two sets of teeth, which make their appearance at different periods of life. Those of the first set are temporary and appear during the first and second years; they are called the *deciduous* or *milk* teeth. Those of the second set begin to replace the deciduous set about the sixth year; they are all established by the twenty-fifth year, and, since they may continue until old age, are named the *permanent* teeth.

FIG. 1059.—The teeth and jaws. Right lateral aspect.



The *deciduous teeth* are twenty in number: four incisors, two canines, and four molars in each jaw.

The *permanent teeth* are thirty-two in number: four incisors, two canines, four premolars, and six molars in each jaw.

The dental formulæ may be represented as follows:

Deciduous Teeth.

	mol.	can.	in.	in.	can.	mol.	
Upper jaw	2	1	2	2	1	2	Total 20
Lower jaw	2	1	2	2	1	2	

Permanent Teeth.

	mol.	premol.	can.	in.	in.	can.	premol.	mol.	
Upper jaw .	3	2	1	2	2	1	2	3	Total 32
Lower jaw .	3	2	1	2	2	1	2	3	

General characteristics.—Each tooth consists of three portions: the *crown*, projecting beyond the gum; the *root*, imbedded in the alveolus; and the *neck*, the constricted portion between the crown and the root.

The roots of the teeth are firmly implanted in the alveoli of the maxillæ and mandible. Each alveolus is lined by periosteum which invests the tooth as far as its neck, and is continuous above with the fibrous tissue of the gums.

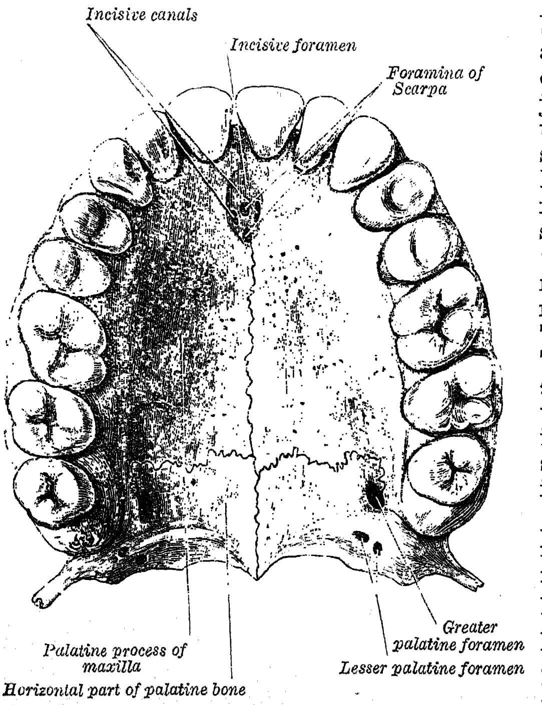
In consequence of the curve of the dental arch, terms such as anterior and posterior, if applied to the teeth, would be misleading and confusing. Special terms are therefore used to indicate the different surfaces of a tooth: the surface directed towards the lips or cheek is known as the *labial* or *buccal* surface; that directed towards the tongue is described as the *lingual* surface; those surfaces which touch neighbouring teeth are termed *surfaces of contact.* In the case of the incisor and canine teeth the surfaces of contact are medial and lateral; in the premolar and molar teeth they are anterior and posterior.

The superior dental arch is larger than the inferior, so that in the normal condition the teeth of the maxillæ slightly overlap those of the mandible both in front and at the sides. The upper central incisors are wider than the lower, and the teeth of the upper and lower sets do not quite correspond to each other when the mouth is closed. Thus the upper canine tooth rests partly on the lower canine and partly on the first premolar, and the cusps of the upper molar teeth lie behind the corresponding cusps of the lower molar teeth. The dental arches, however, end at nearly the same points behind because the upper molars, especially the third, are smaller than the lower.

The Permanent Teeth (figs. 1059 to 1062)

The **incisor teeth** are so named because they present sharp cutting edges, adapted for biting the food. They are eight in number, and form the four front teeth in each dental arch.

Fig. 1060.—The permanent teeth of the upper dental arch. Inferior aspect.

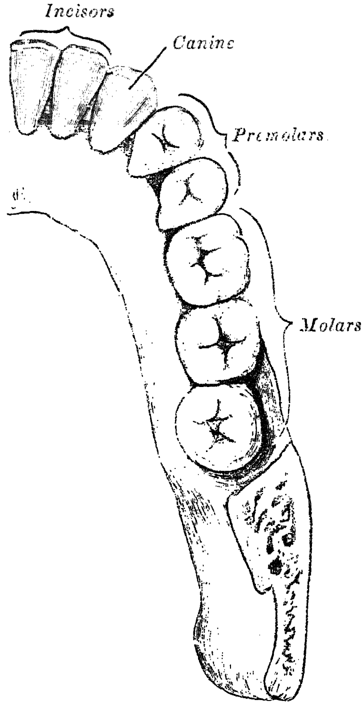


The *crown* of each is directed vertically, and is chisel-shaped, being bevelled so as to present a sharp horizontal cutting edge, which, before being subjected to attrition, presents three small prominent points separated by two notches. It is convex on its labial surface; concave on its lingual surface, where, in the teeth of the upper arch, it is frequently marked by a V-shaped eminence, situated near the gum. This is known as the *cingulum.* The *neck* is constricted. The *root* is long, single, conical, transversely flattened, thicker in front than behind, and slightly grooved on either side in the direction of its length.

The *upper incisors* are larger and stronger than the lower, and are directed obliquely downwards and forwards. They overlap the lower incisors and their free edges are consequently bevelled at the expense of their lingual surfaces. Their roots are conical and nearly cylindrical. The central upper incisors are larger than the lateral.

The *lower incisors* are smaller than the upper. They are placed vertically and are somewhat bevelled in front, where they have been worn down by contact with the overlapping edges of the upper teeth. Their roots are flattened at the sides. The central lower incisors are smaller than the lateral, and are the least of all the incisors.

Fig. 1061.—The permanent teeth of the right half of the lower dental arch. Superior aspect.



The **canine teeth** (cuspids) are four in number, two in the upper, and two in the lower arch, one being placed lateral to each lateral incisor. They are larger and stronger than the incisors, and their roots sink deeply into the bones and cause well-marked prominences upon their surfaces.

The *crown* of each is large and conical, very convex on its labial surface, a little hollowed and uneven on its lingual surface, and tapering to a blunted point or cusp, which projects beyond the level of the other teeth. The *root* is single, but longer and thicker than that of the incisors ; it is conical in form, and marked by a slight groove on either side.

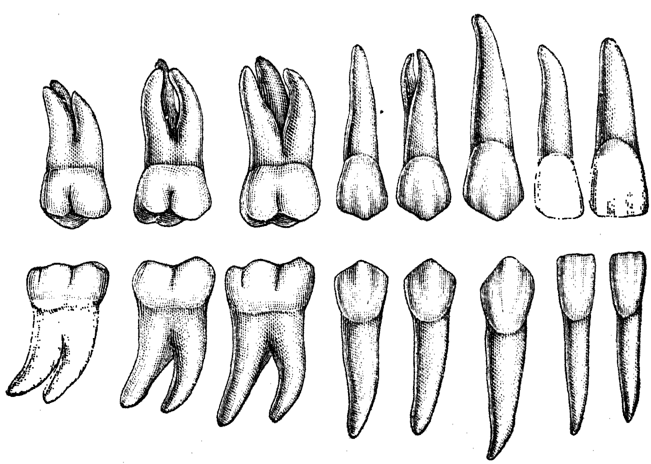
The *upper canine teeth* (popularly called *eye-teeth*) are larger and longer than the lower, and usually present a distinct cingulum.

The *lower canine teeth* are placed nearer the middle line than the upper so that their summits correspond to the intervals between the upper canines and lateral incisors. The roots of the lower canines are occasionally double.

The **bicuspid teeth** or **premolars** are eight in number, four in each arch. They are situated lateral to and behind the canine teeth, and are smaller and shorter than these.

The *crown* of each is compressed from before backwards, and surmounted by two pyramidal eminences or cusps, a labial and a lingual, separated by a groove. Of the two cusps the labial is the larger and more prominent. The

Fig. 1062.—The permanent teeth of the right side. (Burchard.)



neck is oval. The *root* is generally single, but presents in front and behind a deep groove, which indicates a tendency in the root to become double.

The *upper premolars* are larger, and show a greater tendency to the division of their roots than the lower; this is especially the case in the first upper premolar. The roots of the *lower premolars* are nearly cylindrical.

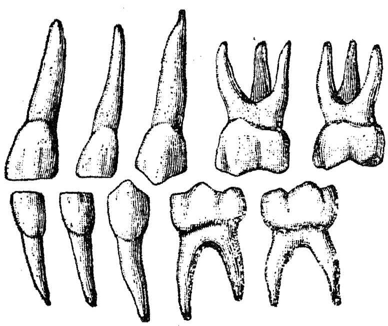
The **molar teeth** are the largest of the permanent set, and their broad crowns are adapted for grinding the food. They are twelve in number, six in each arch, three being placed behind each second premolar.

The *crown* of each is nearly cubical in form, convex on its buccal and lingual surfaces, flattened on its surfaces of contact; it is surmounted by four or five cusps or tubercles, separated from each other by a crucial depression; hence the molars are sometimes termed *multicuspids*. The *neck* is distinct, large, and rounded.

The *upper molars*.—As a rule the first of the upper molars is the largest, and the third the smallest. The crown of the first has usually four cusps; that of the second, three or four; that of the third, three. Each upper molar has three roots, two of which are buccal, and nearly parallel to one another; the third is lingual and diverges from the others as it ascends. The roots of the third molar (dens serotinus or wisdom-tooth) are more or less fused together.

The *lower molars*.—The lower molars are larger than the upper. On the crown of the first there are usually five cusps; on the crowns of the second and third, four or five. Each lower molar has two roots, an anterior and a posterior, which are curved backwards; both roots are grooved longitudinally, indicating a tendency to division. The two roots of the third molar are more or less united.

FIG. 1063.—The deciduous teeth of the left side.



THE DECIDUOUS TEETH (fig. 1063)

The **deciduous or milk-teeth** resemble in form the teeth which bear the same names in the permanent set; they are, however, smaller and their necks are more constricted. The second molar is the largest of the deciduous teeth. The first upper molar has three cusps, the second has four. The first lower molar has four cusps; the second has five. The roots of the deciduous molars are smaller than those of the permanent molars; they are also more divergent, owing to the fact that the crowns of the permanent molars are lodged between them. The deciduous molars are replaced by the permanent premolars.

THE STRUCTURE OF THE TEETH

On making a vertical section through a tooth (figs. 1064 to 1067), a cavity is seen in the crown and in the centre of each root; it opens by a minute orifice at the extremity of the latter. This is called the *pulp cavity*, and contains the *dental pulp*, a loose connective tissue richly supplied with blood-vessels and nerves which enter the cavity through the small aperture at the point of each root. Some of the cells of the pulp are arranged as a layer on the wall of the pulp cavity; they are named *odontoblasts*, and during the development of the tooth are columnar in shape, but after the dentine is fully formed they become flattened. Each sends a fine process into a canaliculus in the dentine.

The solid portion of the tooth consists of (1) the *ivory* or *dentine*, which forms the bulk of the tooth; (2) the *enamel*, which covers the exposed part of the crown; and (3) a thin layer of bone, the *cement* or *crusta petrosa*, which covers the root or roots.

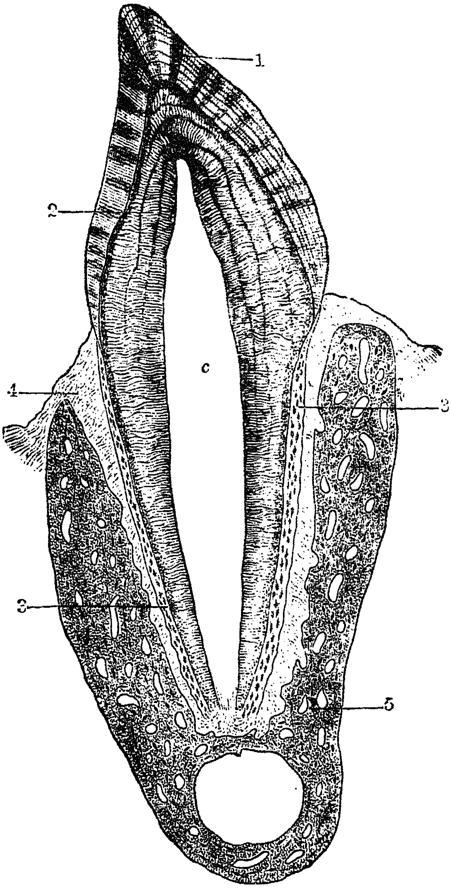
The **dentine** (substantia eburnea) (fig. 1067) is a modification of osseous tissue, from which it differs, however, in structure. On microscopic examination it is seen to consist of a number of minute wavy and branching tubes, the *dental canaliculi*, imbedded in a dense homogeneous substance, the *matrix*.

The *dental canaliculi* (fig. 1067) are placed parallel with one another, and open at their inner ends into the pulp cavity. In their course to the periphery they present two or three curves, and are twisted on themselves in a spiral direction. They vary in direction: thus in a tooth of the mandible they are vertical in the upper portion of the crown, becoming oblique and then horizontal in the neck and upper part of the root, while towards the lower part of the root they are inclined downwards. In their course they divide and subdivide, and, especially in the root, give off minute branches, which join together in loops in the

matrix, or end blindly. Near the periphery of the dentine, the finer ramifications of the canaliculi terminate imperceptibly by free ends. The dental canaliculi have definite walls consisting of an elastic homogeneous membrane, the *dentinal sheath of Neumann*, which resists the action of acids; they contain slender cylindrical prolongations of the odontoblasts, named *Tomes' fibres* or *dentinal fibres*.

The *matrix* is translucent, and contains the chief part of the earthy matter of the dentine. In it are a number of fine fibrils, which are continuous with the fibrils of the dental pulp. After the earthy matter has been removed by steeping a tooth in weak acid, the animal matter may be torn into laminæ which run parallel with the pulp cavity, and across the

FIG. 1064.—A vertical section through a tooth *in situ*. ×15.



c is placed in the pulp cavity, opposite the neck of the tooth; the part above it is the crown, that below is the root. 1. Enamel with radial and concentric markings. 2. Dentine with tubules and contour lines. 3. Cement or crusta petrosa, with bone-cells. 4. Dental periosteum. 5. Mandible.

FIG. 1065.—A vertical section through a molar tooth.

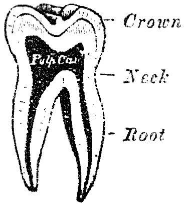
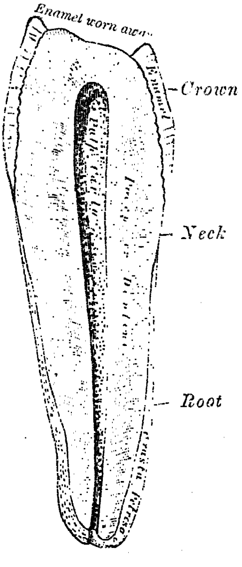


FIG. 1066.—A vertical section through a premolar tooth. (Mandible.)

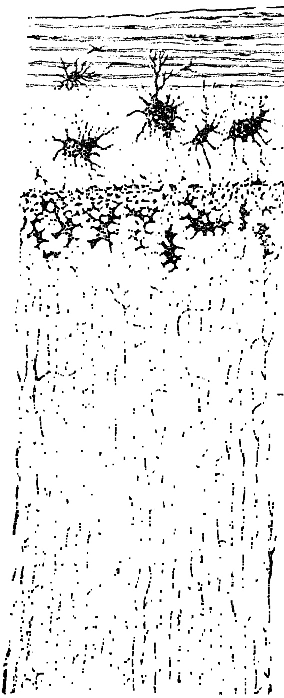


canaliculi. The planes separating these laminæ are indicated in a section of dry dentine by a series of somewhat parallel lines—the *contour lines of Owen*—composed of imperfectly calcified dentine. In consequence of the imperfection in the calcifying process, little irregular cavities are left, termed *interglobular spaces* (fig. 1067). A series of these spaces is found towards the outer surface of the dentine, where they form a layer which is sometimes known as the *granular layer of Tomes*. They have received their name from the fact that they are surrounded by minute nodules or globules of dentine. Other curved lines, the *lines of Schreger*, may be seen parallel to the surface; they are due to the optical effect of simultaneous curvature of the dentinal fibres.

Chemical composition.—According to Berzelius and von Bibra, dentine consists of 28 parts of animal, and 72 parts of earthy, matter. The animal matter is converted, by boiling, into gelatin. The earthy matter consists of phosphate, carbonate, and a trace of fluoride, of calcium, phosphate of magnesium, and other salts; over 80 per cent. of the earthy matter consists of calcium phosphate.

The enamel (substantia adamantina) is the hardest and most compact part of the tooth, and forms a thin crust over the exposed part of the crown, as far as the commencement of the root. It is thickest on the grinding surface of the crown, until worn away by attrition (fig. 1066), and becomes thinner towards the neck. The cement may overlap, or be overlapped by, the enamel, but they generally meet without overlapping. Sections usually show a series of brown lines which form acute angles with the contour of the underlying dentine. The enamel consists of minute rods termed *enamel-fibres* or *enamel-prisms* (prismata adamantina). They lie parallel with one another, their inner ends resting upon the dentine, which presents a number of minute depressions for their reception; their outer ends form the free surface of the crown. The enamel-fibres are directed vertically on the summit of the crown, and more or less horizontally at the sides; they are about 4μ in diameter, and pursue a somewhat wavy course. Each enamel-fibre is a six-sided prism and presents numerous dark transverse shadings; these shadings are probably due to the manner in which the columns are developed in successive stages, producing shallow constrictions, as will be subsequently explained. Numerous minute interstices intervene between the enamel-fibres near their dentinal ends.

Fig. 1067.—A transverse section through a portion of the root of a canine tooth. ×300. (From Stricker's Handbook of Histology.)



Chemical composition.—Enamel consists of from 98 to 99 per cent. of earthy matter, and from 1 to 2 per cent. of animal matter. The earthy matter consists of phosphate of lime, with traces of fluoride and carbonate of calcium, phosphate of magnesium, and other salts. Tomes asserts that there is no animal matter in properly calcified enamel.

The crusta petrosa or cement (substantia ossea) (figs. 1064, 1067), is disposed as a thin layer on the roots of the teeth, from the enamel to the apex of each root. In structure and chemical composition it resembles bone. It contains a few lacunæ and canaliculi; the canaliculi of adjacent lacunæ intercommunicate as in ordinary bone; and those more deeply placed join with the adjacent dental canaliculi. Normal cement is non-vascular.

As age advances, the cement increases in thickness, and gives rise to bony growths or exostoses, common in the teeth of the aged. The pulp cavity also becomes partially filled up by a hard substance, intermediate in structure between dentine and bone (*secondary* or *adventitious dentine*, Tomes); it appears to be formed by a slow conversion of the dental pulp, which shrinks, or disappears.

Arteries.—The upper molars and premolars receive their blood supply from the posterior superior alveolar branch of the internal maxillary artery; the upper canine and incisors from the anterior superior twigs of the infra-orbital artery. The lower teeth are supplied by the inferior alveolar branch of the internal maxillary artery.

Nerves.—The superior alveolar branches of the maxillary nerve supply the upper, and the inferior alveolar branch of the mandibular nerve the lower, teeth.

The *lymphatics* are described on p. 755.

The Development of the Teeth (figs. 1068 to 1071)

In describing the development of the teeth, the mode of formation of the deciduous teeth must first be considered, and then that of the permanent teeth.

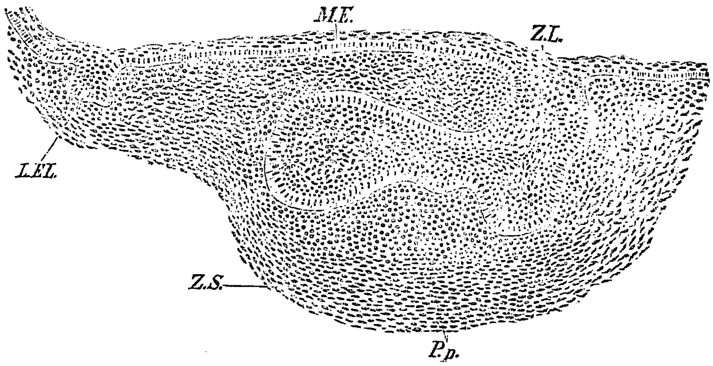
The development of the deciduous teeth begins about the sixth week of fœtal life as a shallow *dental or labiotectal furrow* in the epithelium covering the surface of the future jaw. Along the line of this furrow the epithelium grows into the subjacent mesoderm as a band of cells which splits into a medial (dentogingival) and a lateral (labiogingival) lamina (Bolk*). The labiogingival lamina ultimately separates the alveolar processes from the lips and cheeks. In the dentogingival lamina the enamel-organs of the teeth are developed, and hence it is usually known as the *dental lamina* or *common dental germ.* Bolk has pointed

* L. Bolk, 'Odontological essays,' *Journal of Anatomy*, vols. lv., lvi., lvii.

out that the dental lamina also forms the epithelium of the gums, on the inner surface of the alveolar ridge. The common dental germ forms a flat band of cells, which grows into the substance of the embryonic jaw, at first horizontally, and then, as the teeth develop, vertically, i.e. upwards in the upper jaw, and downwards in the lower jaw. While still maintaining a horizontal direction it has two edges - an *attached edge*, continuous with the epithelium lining the mouth, and a *free edge*, imbedded in the mesodermal tissue of the embryonic jaw.

About the ninth week the dental lamina begins to develop enlargements along its free edge. These are ten in number in each jaw, and each corresponds with a future deciduous tooth. They consist of masses of epithelial cells ; and the cells of the deeper parts of each mass increase rapidly and spread in all directions. Each mass thus comes to assume the shape of a club, connected with the epithelial lining of the mouth by a narrow neck, embraced by mesoderm. These masses are now known as *special dental germs*. After a time the lower expanded portion of each mass inclines outwards, so as to form an angle with the superficial constricted portion, which is sometimes known as the *neck* of the special dental germ. About the tenth week the mesodermal tissue beneath the special dental germs becomes differentiated into papillæ ; these come in contact with the special dental germs, which become folded over them like a hood or cap. There is, at this stage, a

FIG. 1068.—A sagittal section through the first lower deciduous molar of a human embryo 30 mm. long. × 100. (Röse.)



L.E.L. Labiogingival lamina, here separated from the dental lamina. *M.E.* Mouth-epithelium. *P.p.* Bicuspidate papilla, capped by the enamel germ. *Z.L.*, placed over the shallow dental furrow, points to the dental lamina, which is spread out below to form the enamel germ of the future tooth. *Z.S.* Condensed tissue forming dental sac.

papilla (or papillæ) which has already begun to assume somewhat the shape of the crown of the future tooth, and from which the dentine and pulp of the tooth are developed, surmounted by a dome or cap of epithelial cells from which the enamel is derived.

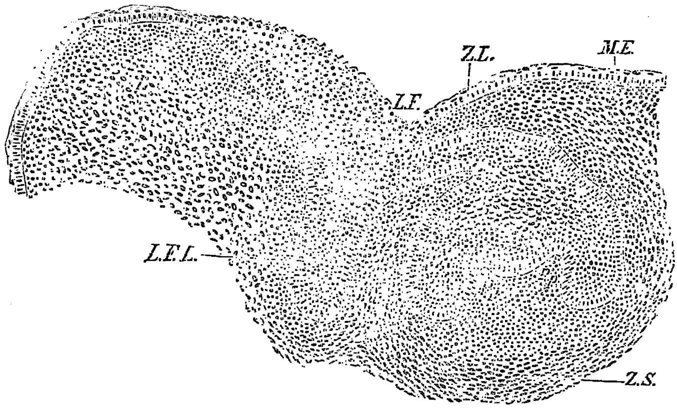
While these changes are going on, the dental lamina extends backwards behind the special dental germ of the second deciduous molar tooth, and about the seventeenth week of fœtal life, it presents an enlargement, the special dental germ for the first permanent molar, soon followed by the formation of a mesodermal papilla for the same tooth. About the fourth month after birth a further extension backwards of the dental lamina occurs, with the formation of another special dental germ and its corresponding papilla for the second molar. The process is repeated for the third molar, the papilla of which appears about the fifth year of life.

After the formation of the special dental germs, the dental lamina undergoes atrophic changes and becomes cribriform, except on the lingual aspect of each of the special germs of the temporary teeth, where it undergoes a local thickening to form the special dental germ of each of the successional permanent teeth—i.e. the ten anterior ones in each jaw. Here the same process goes on as has been described in connexion with those of the deciduous teeth : that is, they recede into the mesoderm, behind the germs of the deciduous teeth. As they recede they become club-shaped, form expansions at their distal ends, and finally meet papillæ which have been formed in the mesoderm. The apex of each papilla indents the dental germ which forms a cap for it, and becomes converted into the enamel, while the papilla forms the dentine and pulp of the permanent tooth.

The special dental germs consist at first of round or polyhedral epithelial cells. After the formation of the papillæ, these cells undergo a differentiation into three layers. Those in contact with the papilla become elongated, and form a stratum of well-marked columnar epithelium. These cells form the enamel-fibres, and are therefore termed *enamel-cells* or *ameloblasts*. The cells of the outer layer of the special dental germ are cubical in form, and are named the *external enamel epithelium*. The intermediate cells become stellate in shape

and form a network into which fluid is secreted; this has the appearance of a jelly, and to it the names of *stellate reticulum* or *enamel-pulp* are given. Between the stellate reticulum and the layer of ameloblasts there is a *stratum intermedium* consisting of two or three layers of round or polygonal cells. The special dental germ, thus transformed, is now named the *enamel-organ* (fig. 1070).

Fig. 1069.—A sagittal section through the canine tooth of an embryo 40 mm. long. ×100. (Röse.)

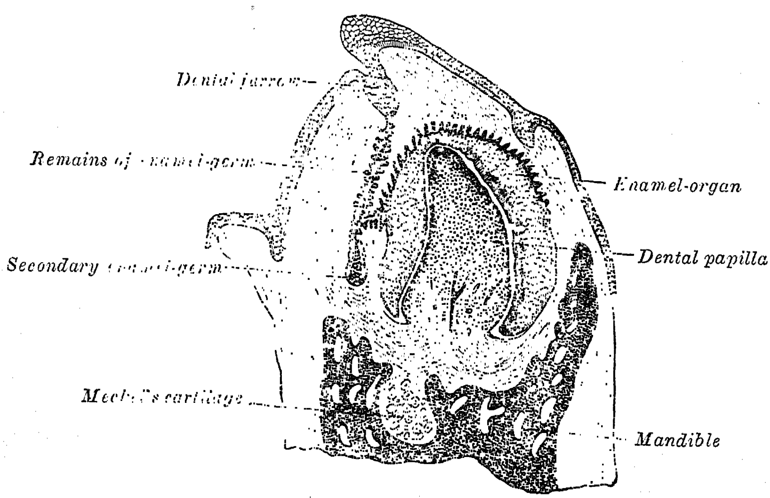


L.F. Labiodental furrow. The other lettering as in fig. 1068.

Bolk (loc. cit.) has pointed out that in mammals, with one or two exceptions, the enamel-organ is, during a certain phase of development, connected with the common dental germ by a *medial* and a *lateral enamel band,* separated by what he names the *enamel-niche.* These two bands unite and convert the niche into a short tunnel which is filled with mesoderm, and is open posteriorly. The lateral enamel-band degenerates and is broken up into epithelial islets.

While these changes are going on, a sac is formed around each enamel-organ from the mesodermal tissue. This is known as the *dental sac,* and is a vascular membrane of connective tissue. It encloses the whole tooth germ, and causes the neck of the enamel-organ to atrophy and disappear; so that the connexion between the enamel-organ and the superficial epithelium is severed.

Fig. 1070.—A vertical section through the mandible of an early human fœtus. ×25.



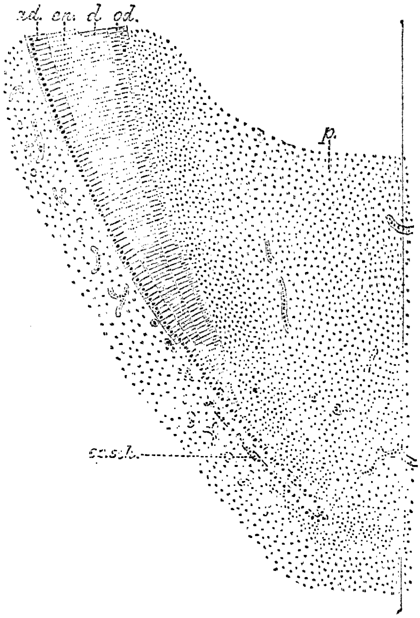
The formation of the enamel.—The enamel is formed exclusively from the enamel-cells or ameloblasts of the special dental germ (fig. 1071), either by direct calcification of the

columnar cells, which become elongated into the enamel-fibres, or, as is more generally believed, as a secretion from the ameloblasts, within which calcareous matter is subsequently deposited.

The process begins at the ends of the enamel-cells in contact with the dental papilla. Here a fine globular deposit takes place, being apparently shed from the ends of the ameloblasts. It is known by the name of the *enamel-droplet*, and resembles keratin in its resistance to the action of mineral acids. This droplet then becomes fibrous and calcifies, and forms the first layer of the enamel; a second droplet now appears and calcifies, and so on; successive droplets of keratin-like material are shed from the ameloblasts and form successive layers of enamel, the ameloblasts gradually receding as each layer is produced, until at the termination of the process they have almost disappeared. The enamel-pulp or stellate reticulum and the stratum intermedium atrophy and disappear, so that the newly formed calcified material and the external enamel-epithelium come into apposition. The crown of the tooth is covered for a time by a distinct membrane, known as the *cuticula dentis*, or *Nasmyth's membrane*, and believed to be developed from the external enamel-epithelium. It forms a horny layer, which may be separated from the subjacent calcified mass by the action of strong acids. It is marked by the hexagonal impressions of the enamel-fibres, and when stained by nitrate of silver, shows the characteristic lines of interepithelial cement.

The formation of the dentine.—As before stated, the first germs of the dentine are the papillæ, which grow upwards into the enamel-germs and become covered by them, both being enclosed in the dental sacs, in the manner above described. Each papilla then consists of round cells, and is very vascular, and soon begins to assume the shape of the future tooth. The next step is the appearance of the *odontoblasts*, which have a relation to the development of the teeth somewhat similar to that of the osteoblasts to the formation of bone; they are formed from the superficial cells of the papilla; these cells become elongated, one end of the elongated cell resting against the epithelium of the special dental germs, the other being tapered and often branched. By the direct transformation of the peripheral ends of these cells, or by a secretion from them, a layer of uncalcified matrix (*prodentine*) is formed, which caps the cusp, or cusps if there be more than one, of the papilla. This matrix becomes fibrillated, and in it islets of calcification make their appearance, and, coalescing, give rise to a continuous layer of calcified material which covers each cusp and constitutes the first layer of dentine. The odontoblasts retire towards the centre of the papilla, and, as they do so, produce successive layers of dentine—that is to say, they form the dentinal matrix in which calcification subsequently takes place. As they recede from the periphery of the papilla, they leave behind them filamentous processes of cell-protoplasm; these are surrounded by the calcified material, and thus the dental canaliculi are formed; the processes of protoplasm contained within these constitute the dentinal fibres (Tomes' fibres). The central part of the papilla does not undergo calcification, but persists as the pulp of the tooth. In certain places uncalcified portions of the matrix remain between the successive layers of dentine, and give rise to the interglobular spaces alluded to above.

FIG. 1071.—A longitudinal section through the lower part of a growing tooth, showing the extension of the layer of ameloblasts beyond the crown to mark off the limit of formation of the dentine of the root. (Röse.) (From Quain's Elements of Anatomy.)



ad. Ameloblasts, continuous below with *ep. sch.*, the epithelial sheath. *d.* Dentine. *en.* Enamel. *od.* Odontoblasts. *p.* Pulp.

The formation of the cement.—The root of the tooth begins to be formed shortly before the crown emerges through the gum, but is not completed until some time afterwards. Its form is determined by a downgrowth of the epithelium of the dental germ, which extends below the region where the enamel is to be formed, almost as far as the situation of the apex of the future root (fig. 1071); this fold of epithelium is known as the *epithelial sheath*. The vascular tissues of the dental sac then break through the epithelial sheath, and spread over the surface of the root as a layer of bone-forming material. In this layer osteoblasts make their appearance, and the process of ossification goes on as in the intramembranous ossification of bone. The remains of the epithelial sheath may sometimes be seen in the adult as isolated groups of cells in the alveolodental periosteum.

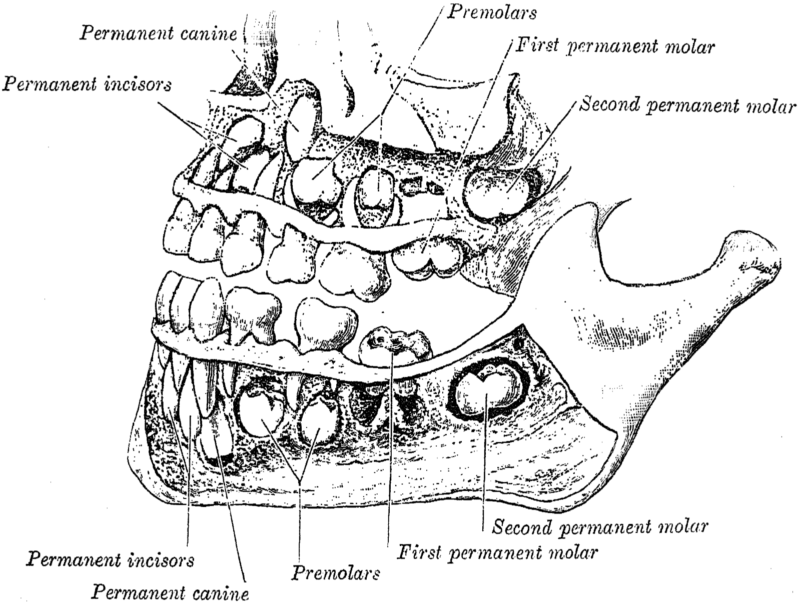
The formation of the alveoli.—About the fourteenth week of embryonic life the dental lamina is enclosed in a trough or groove of mesodermal tissue, which at first is common to all the dental germs, but subsequently is divided by septa into loculi, each loculus containing the special dental germ of a deciduous tooth and its corresponding permanent tooth. After birth each cavity becomes subdivided, so as to form separate loculi for each deciduous tooth and its corresponding permanent tooth. Although at one time the whole of the growing tooth is contained in the cavity of the alveolus, the latter never completely encloses it, since there is always an aperture over the top of the crown filled by soft tissue, by which the dental sac is connected with the surface of the gum, and which in the permanent teeth is called the *gubernaculum dentis.*

The **development of the permanent teeth.**—Developmentally considered the permanent teeth may be divided into two sets: (1) the *successional permanent teeth* which replace the deciduous teeth, and, like them, are ten in number in each jaw; and (2) the *superadded permanent teeth* which have no deciduous predecessors, but are developed behind the temporary molars. The superadded permanent teeth are the three permanent molars, the molars of the deciduous set being replaced by the permanent premolars. During their development the successional permanent teeth, enclosed in their sacs, are placed on the lingual side of the deciduous teeth, but are separated from them by bony partitions. As the crown of the permanent tooth grows, absorption of the bony partition and of the root of the deciduous tooth takes place, through the agency of *osteoclasts* which appear at this time, and finally nothing but the crown of the deciduous tooth remains. This is shed or removed, and the permanent tooth takes its place.

The superadded permanent teeth are developed in the manner already described, by extensions backward of the posterior part of the dental lamina in each jaw (p. 1107).

The *eruption of the teeth.*—When the calcification of the different tissues of the tooth is sufficiently advanced to enable it to bear the pressure to which it will be subjected, eruption takes place, the tooth making its way through the gum. The eruption of the deciduous teeth commences about the seventh month after birth, and is completed about the end of the second year, the teeth of the lower jaw preceding those of the upper.

FIG. 1072.—The teeth of a child aged about seven years.



C. S. Tomes gives the following as the most usual times of eruption of the deciduous teeth:

Lower central incisors	6 to 9 months
Upper incisors	8 to 10 months
Lower lateral incisors and first molars	15 to 21 months
Canines	16 to 20 months
Second molars	20 to 24 months

There are, however, considerable variations in these times. According to Holt: a child at the age of one year should have six teeth; at the age of a year and half, twelve teeth; at the age of two years, sixteen teeth; and at the age of two and a half years, twenty teeth.

Calcification of the permanent teeth proceeds in the following order in the lower jaw (in the upper jaw it takes place a little later): the first molars, soon after birth; the incisors, and canines, about six months after birth; the premolars, at the second year, or a little later; the second molars, about the end of the second year; the third molars, about the twelfth year.

The eruption of the permanent teeth takes place at the following periods, the teeth of the lower jaw preceding those of the upper by short intervals:

First molars	6th year
Two central incisors	7th year
Two lateral incisors	8th year
First premolars	9th year
Second premolars	10th year
Canines	11th to 12th year
Second molars	12th to 13th year
Third molars	17th to 25th year

Towards the sixth year, before any of the deciduous teeth are shed, there are twenty-four teeth in each jaw, viz. the ten deciduous teeth and the crowns of all the permanent teeth except the third molars (fig. 1072).

Applied Anatomy.—As a consequence of local irritation or of chronic digestive disturbances occurring during their eruption, both the deciduous and the permanent teeth may show defective development or irregular transverse furrows and erosions; this is particularly the case with the incisors. A characteristic malformation of the two upper central permanent incisors is seen in patients with inherited syphilis, and was first described by Hutchinson. Here there is a crescentic notch in the anterior surface and at the cutting edge of the tooth, which is peg-shaped, stunted, and set obliquely in the gum, pointing either medialwards or lateralwards.

Numerous forms of innocent *tumour* arising from the teeth, or from their constituent layers, have been described under the general name of *odontoma*.

Infection of the pulp of a tooth by bacteria gaining access thereto in consequence of dental caries gives rise to the common and very painful *alveolar abscess*; starting in the apical space between the root of the tooth and its alveolar socket, the pus from such an abscess may make its way into the maxillary antrum, or burst through the hard palate or cheek. A more superficial abscess forming between the root of a tooth and the gum is known as a *gum-boil*.

The Tongue (Lingua)

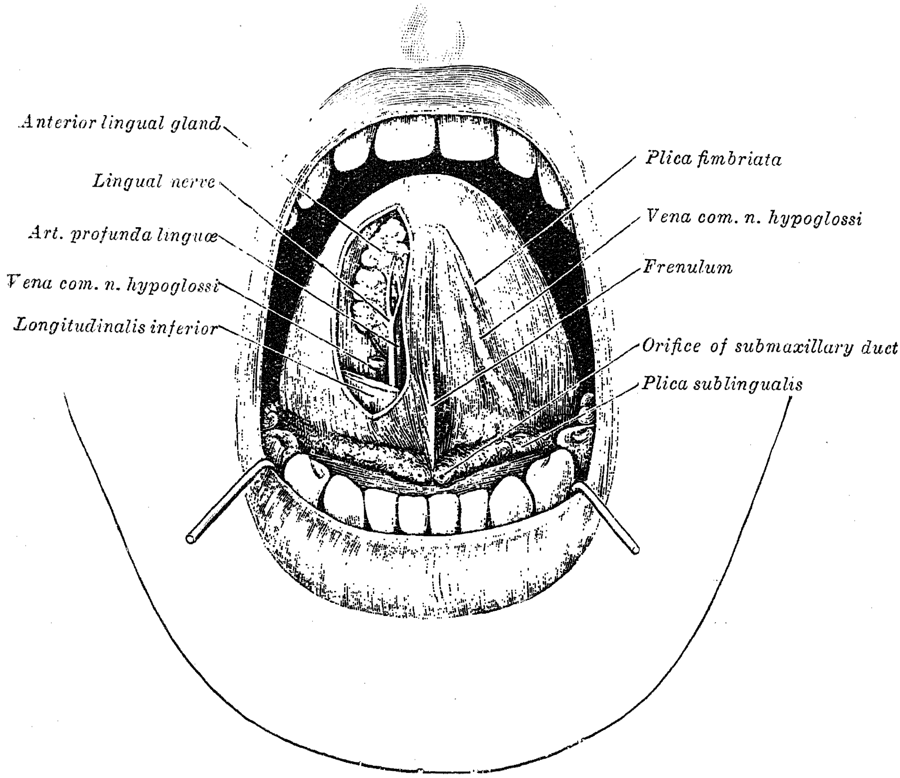
The **tongue**, a muscular organ intimately associated with the functions of taste, speech and deglutition, is situated partly in the mouth, and partly in the pharynx. It is attached to the hyoid bone by the Hyoglossi, to the mandible by the Genioglossi, to the styloid processes by the Stylopharyngei, and to the soft palate by the Glossopalatini; it also gives origin to a few fibres of the Constrictor pharyngis superior. It possesses a root, an apex, a curved dorsum, and an inferior surface.

The *root* of the tongue is attached to the hyoid bone and the mandible, and between these bones is in contact with the Geniohyoidei and the Mylohyoidei. The *dorsum* is convex from before backwards, and from side to side, and is divided into a superior and a posterior part by a V-shaped furrow, the *sulcus terminalis*, the limbs of which run lateralwards and forwards from a median pit, the *foramen cæcum*, to the glossopalatine arches. The foramen cæcum marks the site of the upper end of the thyreoid diverticulum (p. 134), and the sulcus terminalis serves as the boundary between the oral part or anterior two-thirds, and the pharyngeal part or posterior one-third, of the tongue. These two parts differ in their development and nerve-supply.

The *oral part* of the tongue is placed in the cavity and floor of the mouth; its *apex* rests against the incisor teeth; its *borders* are free and in contact with the gums and teeth; its *superior surface* is in relation with the hard and soft palates. On each border, just in front of the Glossopalatine arch, are

four or five vertical folds, the *folia linguæ*, which represent the papillæ foliatæ of the rabbit's tongue. The mucous membrane on the superior surface of the oral part is marked by a median furrow (fig. 1074), is intimately adherent to the subjacent muscle, and is covered with papillæ. The mucous membrane on the inferior surface is smooth, and of a purplish colour; it is reflected from the tongue to the floor of the mouth and the gums. In the middle line it is raised into a crescentic fold, the *frenulum linguæ*, at each side of which is the opening of the submaxillary duct. Lateral to the frenulum, the lingual vein is seen shining through the mucous membrane, and at the lateral side of the vein there is a fringed fold of mucous membrane, named the *plica fimbriata*, which is directed forwards and medialwards towards the apex. The oral part

FIG. 1073.—The cavity of the mouth. The apex of the tongue is turned upwards, and on the right side a superficial dissection of its under surface has been made.



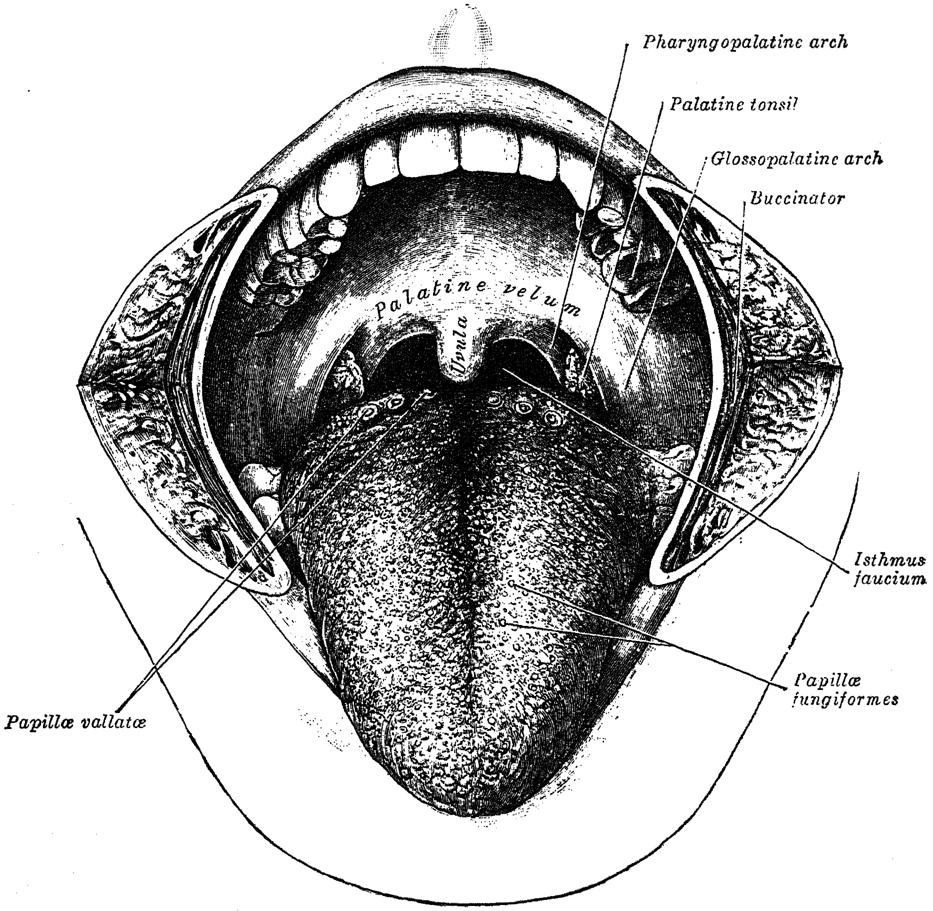
of the tongue is developed from the lingual swellings of the mandibular arch, and to a small extent from the tuberculum impar (p. 134). Its nerve of ordinary sensation is the lingual; its nerve of taste, the chorda tympani.

The *pharyngeal part* of the tongue lies behind the glosso-palatine arches and the isthmus faucium; its posterior surface (sometimes named the *base* of the tongue) forms the anterior wall of the oral part of the pharynx. The mucous membrane covering it is reflected laterally on to the tonsils and the pharyngeal wall, and posteriorly on to the epiglottis, where it forms a median (glosso-epiglottic) fold, and two lateral (pharyngo-epiglottic) folds. It is devoid of papillæ, but exhibits a number of low elevations, due to the presence of underlying nodules of lymphoid tissue, which are imbedded in the submucous tissue, and collectively constitute the *lingual tonsil*. The pharyngeal part of the tongue is developed from the copula, which is formed by the forward growth and fusion of the ventral ends of the second and third visceral arches (p. 134). Its nerves of ordinary sensation and of taste are derived from the glosso-pharyngeal.

The *papillæ of the tongue* (fig. 1074) are projections of the corium. They are thickly distributed over the anterior two-thirds of the dorsum, giving to this part its characteristic roughness. They are grouped under the terms papillæ vallatæ, papillæ fungiformes, papillæ conicæ, and papillæ simplices.

The *papillæ vallatæ* (fig. 1075) are of large size, and vary from eight to twelve in number. They are situated on the dorsum of the tongue, and form a V-shaped row immediately in front of and parallel with the sulcus terminalis. Each papilla is from 1 mm. to 2 mm. in diameter, and is attached within a

FIG. 1074.—The cavity of the mouth. The cheeks have been slit transversely and the tongue pulled forwards.

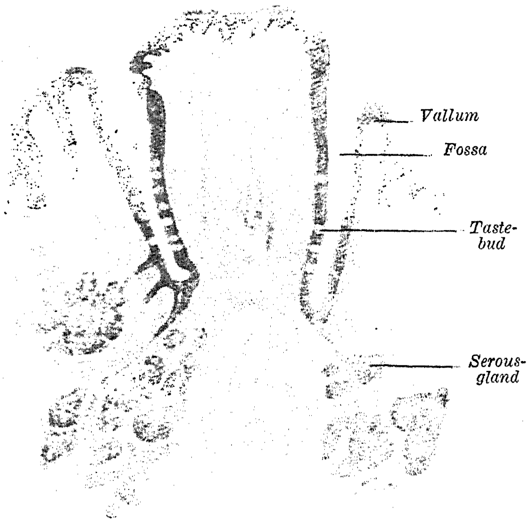


circular depression of the mucous membrane; each depression is surrounded by a wall (vallum), and between this and the papilla is a circular sulcus or fossa. The papilla is shaped like a truncated cone, the smaller end being attached to the tongue; the broader end projects a little above the surface of the tongue, and is studded with numerous small secondary papillæ subjacent to the epithelial layer. The entire papilla and the surrounding fossa and vallum are covered by stratified squamous epithelium.

The *papillæ fungiformes* (fig. 1076), more numerous than the preceding, are found chiefly at the sides and apex of the tongue, but are scattered irregularly and sparingly over the dorsum. They are easily distinguished from the papillæ conicæ by their large size, round shape, and deep red colour; each exhibits secondary papillæ beneath the epithelium. On the sides of the tongue they are somewhat flattened, and are named *papillæ lenticulares*.

The *papillæ conicæ* (fig. 1077) cover the anterior two-thirds of the dorsum of the tongue. They are very minute, conical or cylindrical in shape, and arranged in rows which run parallel with those of the papillæ vallatæ, excepting at the apex of the tongue, where their direction is transverse. The papillæ conicæ present numerous secondary connective tissue papillæ, but these are more pointed and contain a larger proportion of elastic fibres than the secondary papillæ vallatæ and papillæ fungiformes. The epithelium covering the papillæ conicæ may be split up into filamentous processes, each of which forms the apex of one of the secondary papillæ; these processes are of a whitish tint, owing to the thickness and density of the epithelium, the cells of which are elongated and cornified.

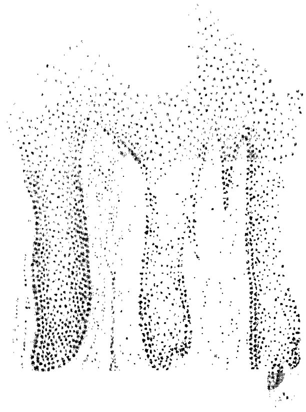
Fig. 1075.—A vertical section through a human papilla vallata. Stained with hæmatoxylin and eosin. × 15.



The *papillæ simplices* are similar to those of the skin, and cover the whole of the mucous membrane of the tongue, as well as the larger papillæ. They consist of closely set microscopic elevations of the corium; each contains a capillary loop, and is covered by epithelium.

Fig. 1076.—A section through a fungiform papilla from the human tongue. Stained with hæmatoxylin and eosin. × 15.

Fig. 1077.—A section through two conical papillæ from the human tongue. Stained with hæmatoxylin and eosin. × 15.



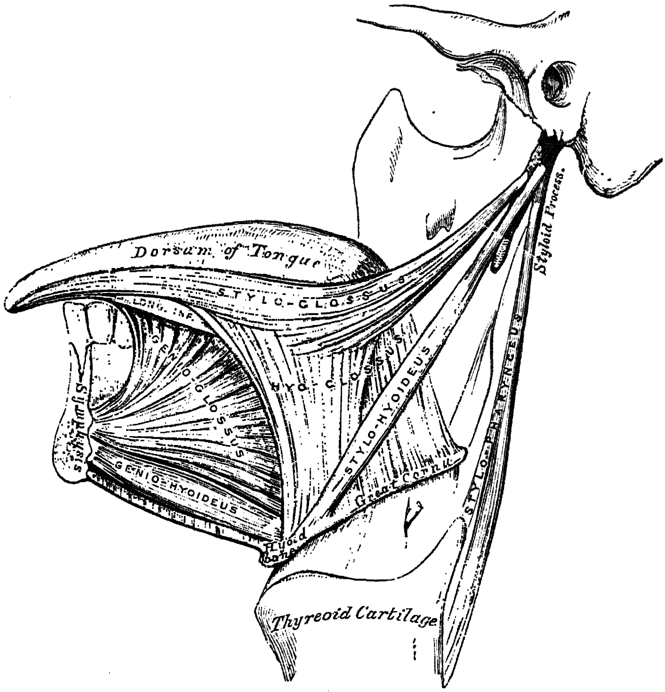
The muscles of the tongue.—The tongue is divided into right and left halves by a median fibrous septum which is fixed below to the hyoid bone. In either half there are two sets of muscles, extrinsic and intrinsic; the former have their origins outside the tongue, the latter are contained within it.

The *extrinsic muscles* (fig. 1078) are:

Genioglossus. Chondroglossus.
Hyoglossus. Styloglossus.
Glossopalatinus.*

The **Genioglossus** is a triangular muscle placed close to and parallel with the median plane. It arises by a short tendon from the superior mental spine on the inner surface of the symphysis of the mandible, just above the origin of

FIG. 1078.—The left extrinsic muscles of the tongue. Lateral aspect.



the Geniohyoideus, and spreads out in a fan-like form. The inferior fibres are attached by a thin aponeurosis to the upper part of the body of the hyoid bone, a few passing between the Hyoglossus and Chondroglossus to blend with the Constrictores pharyngis; the middle fibres pass backwards, and the superior ones upwards and forwards, to enter the whole length of the under surface of the tongue, from the root to the apex. The muscles of opposite sides are separated posteriorly by the septum of the tongue (p. 1117); in front, they are more or less blended owing to the decussation of fasciculi in the median plane.

Nerve-supply.—The Genioglossus is supplied by the hypoglossal nerve.

Actions.—The Genioglossus draws the tongue forwards and protrudes the apex through the mouth. The two muscles acting in their entirety draw the median part of the tongue downwards so as to make the superior surface concave from side to side.

The **Hyoglossus**, thin and quadrilateral, arises from the whole length of the greater cornu, and from the front of the lateral part of the body, of the hyoid bone; it passes almost vertically upwards and enters the side of the tongue, between the Styloglossus and Longitudinalis linguæ inferior. The fibres arising from the body of the hyoid bone overlap those from the greater cornu.

Relations.—The Hyoglossus is in relation by its *superficial surface* with the Digastricus, the Stylohyoideus, Styloglossus, and Mylohyoideus, the submaxillary ganglion, the lingual

* The *Glossopalatinus* (Palatoglossus), although one of the muscles of the tongue, is more closely associated with the soft palate both in situation and function; it is consequently described with the muscles of that structure (p. 1120).

nerve, the hypoglossal nerve and its vena comitans, the ranine vein, the sublingual gland, the deep portion of the submaxillary gland, and the submaxillary duct. By its *deep surface* it is in relation with the stylohyoid ligament, the Genioglossus, the Longitudinalis linguæ inferior, and the Constrictor pharyngis medius, the lingual vessels, and the glosso-pharyngeal nerve.

Nerve-supply.—The Hyoglossus is supplied by the hypoglossal nerve.

Action.—The Hyoglossus depresses the tongue.

The **Chondroglossus** is sometimes described as a part of the Hyoglossus, but it is separated from that muscle by fibres of the Genioglossus which pass to the side of the pharynx. It is about 2 cm. long, and arises from the medial side and base of the lesser cornu and contiguous portion of the body of the hyoid bone; it ascends and blends with the intrinsic muscular fibres of the tongue, between the Hyoglossus and Genioglossus.

A small slip arises occasionally from the cartilago triticea in the lateral hyothyreoid ligament and enters the tongue with the hindermost fibres of the Hyoglossus.

Nerve-supply.—The Chondroglossus is supplied by the hypoglossal nerve.

Action.—The Chondroglossus assists the Hyoglossus in depressing the tongue.

The **Styloglossus**, the shortest and smallest of the three styloid muscles, arises from the anterior and lateral surfaces of the styloid process, near its apex, and from the stylohyoid ligament. Passing downwards and forwards, it divides upon the side of the tongue into two portions; one, longitudinal, enters the side of the tongue near its dorsal surface, blending with the fibres of the Longitudinalis linguæ inferior in front of the Hyoglossus; the other, oblique, overlaps the Hyoglossus and decussates with its fibres.

Nerve-supply.—The Styloglossus is supplied by the hypoglossal nerve.

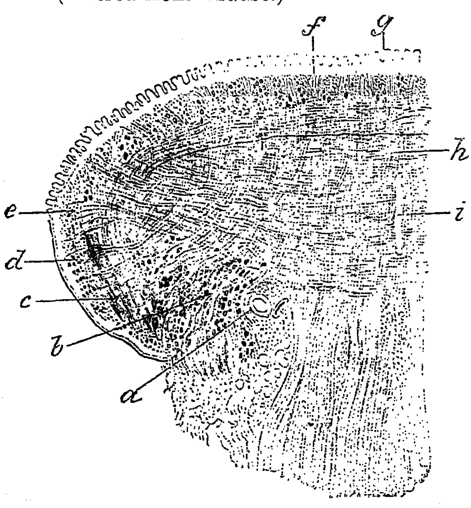
Action.—The Styloglossus draws the tongue upwards and backwards.

The *intrinsic muscles* (fig. 1079) are:

Longitudinalis linguæ superior.	Transversus linguæ.
Longitudinalis linguæ inferior.	Verticalis linguæ.

The **Longitudinalis linguæ superior** is a thin stratum of oblique and longitudinal fibres immediately underlying the mucous membrane on the dorsum of the tongue. It arises from the submucous fibrous layer close to the epiglottis, and from the median fibrous septum, and runs forward to the edges of the tongue, some of its fibres being inserted into the mucous membrane.

Fig. 1079.—A coronal section through the tongue, showing the intrinsic muscles. (Altered from Krause.)



a. Lingual artery. *b.* Longitudinalis inferior. *c.* Hyoglossus. *d.* Styloglossus. *e.* Insertion of Transversus. *f.* Longitudinalis superior. *g.* Papillæ of tongue. *h.* Vertical fibres of Genioglossus intersecting Transversus. *i.* Septum.

The **Longitudinalis linguæ inferior** is a narrow band situated on the under surface of the tongue between the Genioglossus and Hyoglossus. It extends from the root to the apex of the tongue, some of its posterior fibres being connected with the body of the hyoid bone; in front it blends with the fibres of the Styloglossus.

The **Transversus linguæ** consists of fibres which arise from the median fibrous septum and pass lateralwards to be inserted into the submucous fibrous tissue at the sides of the tongue.

The **Verticalis linguæ** is found at the borders of the fore part of the tongue. Its fibres extend from the upper to the under surface of the organ.

Applied Anatomy.—Owing to the presence of the median fibrous septum of the tongue, the anastomosis between the two lingual arteries is not very free. This is a point of considerable importance in connexion with removal of one-half of the tongue, an operation not infrequently resorted to for malignant disease. If the mucous membrane be divided exactly in the middle line, the tongue can be split into halves, without any appreciable hæmorrhage, and the diseased half can then be removed.

Nerve-supply.—The intrinsic muscles of the tongue are supplied by the hypoglossal nerve.

Actions.—The intrinsic muscles are mainly concerned in altering the shape of the tongue; thus, the Longitudinales linguæ superior et inferior tend to shorten it, but the former, in addition, turns the tip and sides upwards so as to render the dorsum concave, while the latter pulls the tip downwards and renders the dorsum convex. The Transversus linguæ narrows and elongates the tongue, and the Verticalis linguæ flattens and broadens it. The complex arrangement of the lingual muscles enables the tongue to assume the forms necessary for the production of the different consonantal sounds; and Macalister * says 'there is reason to believe that the musculature of the tongue varies in different races owing to the hereditary practice and habitual use of certain motions required for enunciating the several vernacular languages.'

Structure of the tongue.—The tongue consists chiefly of muscular tissue, but is partly invested by mucous membrane and a submucous fibrous layer.

The mucous membrane covering the under surface of the tongue is thin, smooth, and identical in structure with that lining the rest of the oral cavity. The mucous membrane of the pharyngeal part of the dorsum of the tongue is thick and freely movable over the subjacent parts. It contains a large number of follicles of lymphoid tissue; each follicle forms a rounded eminence, in the centre of which is a minute orifice leading into a funnel-shaped cavity or recess; around this recess are grouped numerous round or oval nodules of lymphoid tissue, each enveloped by a capsule derived from the submucous fibrous layer, while opening into the bottom of the recess are also seen the ducts of mucous glands. The mucous membrane on the oral part of the dorsum of the tongue is thin, intimately adherent to the muscular tissue, and covered with numerous *papillæ* (p. 1113). It consists of a layer of connective tissue, the *corium* or *mucosa,* covered with epithelium.

The epithelium is of the stratified squamous variety, similar to, but much thinner and less complex than that of the skin; it invests each papilla from root to summit.

The *corium* consists of a dense felt-work of fibrous connective tissue, with numerous elastic fibres, firmly united with the fibrous tissue between the muscular bundles of the tongue. It contains the ramifications of the numerous vessels and nerves from which the papillæ are supplied, large plexuses of lymphatic vessels, and the glands of the tongue.

Glands of the tongue.—The tongue is provided with mucous and serous glands.

The *mucous glands* are similar in structure to the labial and buccal glands. They are numerous in the posterior one-third of the tongue, i.e. behind the papillæ vallatæ, but are also present at the apex and margins. In this connexion the *anterior lingual glands* (glands of Blandin or Nuhn) require special notice. They are situated on the under surface of the apex of the tongue (fig. 1073), one on either side of the frenulum, where they are covered by the mucous membrane and by a fasciculus of muscular fibres derived from the Styloglossus and Longitudinalis inferior. They are from 12 mm. to 20 mm. long, and about 8 mm. broad; each consists of mucous and serous alveoli, and opens by three or four ducts on the under surface of the apex of the tongue.

The *serous glands* occur only at the back of the tongue in the neighbourhood of the taste-buds, their ducts opening for the most part into the fossæ of the papillæ vallatæ. These glands are racemose; the duct of each branches into several minute ducts, which end in alveoli lined by a single layer of more or less columnar epithelium. Their secretion is of a watery nature, and probably assists in distributing the substance to be tasted over the taste area (Ebner).

The *septum* of the tongue is a median fibrous partition which extends throughout the length of the organ, but does not quite reach the dorsum; it gives origin to the Transversus linguæ, and is well displayed in a coronal section of the tongue. Posteriorly it expands in a transverse direction and forms what is known as the *hyoglossal* membrane; this membrane connects the root of the tongue to the hyoid bone, and gives insertion to the inferior fibres of the Genioglossi.

Taste-buds, the end-organs of the gustatory sense, are scattered over the mucous membrane of the mouth and tongue at irregular intervals. They occur especially in the sides of the papillæ vallatæ. They are described under the organs of the senses (p. 983).

Vessels and Nerves.—The main *artery* of the tongue is the lingual branch of the external carotid artery, but the external maxillary and ascending pharyngeal arteries also give branches to it. The *veins* open into the internal jugular vein.

The *lymphatics of the tongue* are described on pp. 756, 757.

* *Text-book of Human Anatomy,* 1889.

The *sensory nerves of the tongue* are: (1) the lingual branch of the mandibular nerve, which is the nerve of ordinary sensibility for the anterior two-thirds of the tongue; (2) the chorda tympani branch of the facial nerve, which runs in the sheath of the lingual nerve, and is generally regarded as the nerve of taste for the anterior two-thirds; this nerve is derived from the sensory root of the facial (nervus intermedius); (3) the lingual branch of the glossopharyngeal nerve, which is distributed to the mucous membrane at the base and sides of the tongue, and to the papillæ vallatæ, and is the nerve of taste and of general sensation for this region; (4) the superior laryngeal nerve, which sends some fine branches to the part near the epiglottis.

Applied Anatomy.—Congenital cysts and fistulæ may develop from persistent remains of thyreoglossal duct (p. 134).

In the event of the lingual artery being accidentally injured, hæmorrhage can be at once controlled by passing the forefinger over the tongue until it touches the epiglottis, and then turning it towards the side on which the artery is to be compressed, and pushing it forcibly against the mandible (Heath).

It is the attachment of the Genioglossi to the mental spines on the inner surface of the symphysis menti which prevents the tongue from falling back and obstructing respiration, and, therefore, anæsthetists always pull forward the mandible and so get the full benefit of this action of these muscles. When in the course of an operation for the removal of cancer of the tongue, these attachments of the Genioglossi are divided, it is necessary to put a suture through the stump of the tongue to hold it forwards.

A consideration of the lymphatics of the tongue (pp. 756, 757) will indicate the extent of the operation necessary for the removal of cancer of the tongue.

The Fauces (fig. 1074)

The aperture by which the mouth communicates with the pharynx is called the *isthmus faucium.* Above, it is bounded by the soft palate; below, by the dorsum of the tongue; and, at the sides, by the glossopalatine arches.

The *glossopalatine arch* (anterior pillar of the fauces) runs downwards, lateralwards, and forwards on either side from the inferior surface of the soft palate to the side of the tongue, and is formed by the projection of the Glossopalatinus (p. 1120) with its covering mucous membrane.

The *pharyngopalatine arch* (posterior pillar of the fauces) lies behind and projects farther towards the middle line than the glossopalatine arch; it runs downwards, lateralwards, and backwards from the margin of the uvula to the side of the pharynx, and is formed by the projection of the Pharyngopalatinus (p. 1121), covered by mucous membrane. On either side the arches are separated below by a triangular recess, the *sinus tonsillaris,* in which the palatine tonsil is lodged.

The **palatine tonsils** (fig. 1074) are two masses of lymphoid tissue, situated in the lateral walls of the oral part of the pharynx. Each tonsil occupies the lower part of the sinus tonsillaris between the glossopalatine and pharyngopalatine arches; the upper part of the sinus is known as the *supratonsillar fossa.* A crescentic or triangular fold of mucous membrane, within which is a layer of fibrous tissue continuous with the capsule of the tonsil, passes backwards from the glossopalatine arch. The upper part of this fold, termed the *plica semilunaris* or *plica supratonsillaris,* stretches between the two arches and forms the medial wall of the supratonsillar fossa; the lower part of the fold, named the *plica triangularis,* forms the medial wall of the anterior and lower parts of the sinus tonsillaris; it overlaps, and is frequently adherent to, the tonsil. The tonsil extends forwards for a variable distance under cover of the plica triangularis and the glossopalatine arch, and upwards around the supratonsillar fossa and into the soft palate. A considerable part of the tonsil is therefore below the level of the surrounding mucous membrane (i.e. imbedded), while the remainder projects as the visible tonsil. In the child the tonsils are relatively (and often absolutely) larger than in the adult, and about one-third of the tonsil is imbedded (Hett and Butterfield *). After puberty the imbedded portion diminishes considerably in size, and the tonsil assumes a disc-like form, flattened from side to side; the shape and size of the tonsil, however, vary considerably in different persons.

The *free surface* of the tonsil presents from twelve to fifteen orifices leading into small crypts or recesses from which numerous follicles branch out into the tonsillar substance.

* G. Seccombe Hett and H. G. Butterfield, *Journal of Anatomy and Physiology,* vol. xliv.

normal conditions in different persons and at different ages should be kept in mind when the chest is being examined. On *inspection* the thorax will be seen to be enlarged and barrel-shaped in emphysema, in which the volume of the lungs is increased by dilatation of their alveoli, or in an acute attack of asthma, or when a large pleural effusion or mediastinal tumour is present. The chest-wall will be flattened or sunken, on the other hand, over an area of lung that has collapsed or become fibrosed, as often happens in chronic pulmonary tuberculosis. The respiratory movements of the chest-wall will be lessened, or even absent, over a part or the whole of the affected side in such acute disorders as pleurisy, pneumonia, or pleural effusion, or in more chronic disease where the underlying lung is fibrosed, or is crushed to one side by a mediastinal tumour; and by the use of the *x*-rays a corresponding loss of movement or displacement of the Diaphragm on the affected side can often be observed. Under normal conditions the intercostal spaces are a little depressed; but when a large effusion or new growth fills up one of the pleural cavities they may be obliterated or even bulging on that side.

On *palpation* the hand can be used to verify the eye's impressions as to the degree of movement, on respiration, of any part of the chest-wall. The facility with which the vibrations produced by the voice are conducted from the larynx by the underlying lung to the hand (in the form of *vocal fremitus*) can also be tested. The vocal fremitus is commonly much increased over the consolidated area in pneumonia or in fibrosis of the lung, and much diminished over a pleural effusion when the lung is pushed up by the fluid towards the top of the pleural cavity. It is also diminished, but to a less extent, in emphysema, and in bronchitis when the bronchi are blocked by secretion. In bronchitis the bubbling of the secretion in the tubes can often be felt by a hand placed on the chest-wall as the patient breathes; and in chronic pleurisy the friction of the two roughened pleural surfaces against one another can sometimes be felt in the same way. It must be remembered that the vocal fremitus in front and behind is normally greater at the right apex than the left. This is because the apex of the right lung lies in close contact with the trachea, while the apex of the left lung is separated from it by the œsophagus and other structures.

On *percussion*, the normal resonance of the pulmonary tissue is found to be increased in emphysema, and in pneumothorax (p. 1080) this hyper-resonance may be still further increased. The resonance is lessened in any condition causing collapse or solidification of the lung-tissue, or when its place is taken by fluid (pleural effusion) or some solid growth (mediastinal tumour). Thus dulness on percussion at the bases of the lungs is common in the hypostatic congestion of the bases seen in heart-failure; dulness at the right base is often due to compression of the lung by enlargement of the liver; some dulness at the apex of a lung is frequently met with in tuberculosis of that part, before the disease has progressed very far. Complete dulness over one side of the chest, back and front alike, except at the apex, is common when a large pleural effusion has taken the lung's place. Von Korányi, Grocco, and others have drawn attention to a triangular patch of dulness along the vertebral column (the paravertebral triangle of dulness) on the unaffected side in pleural effusion; this triangle of dulness is said to be absent in other conditions causing loss of pulmonary resonance on percussion, and is due to shifting over of the contents of the posterior mediastinal cavity towards the sound side. The apex of this triangle is in the middle line at the upper level of the fluid effusion; its base, some 5 cm. to 10 cm. in length, runs horizontally outwards from the middle line at the level where the pulmonary resonance normally comes to an end.

On *auscultation* of the lungs, both in health and disease, the variety of sounds to be heard is very great. It is impossible to give adequate consideration to them here, and for further information reference should be made to the text-books dealing with the subject.

THE DIGESTIVE APPARATUS

The apparatus for the digestion of the food consists of the digestive tube and of certain accessory organs.

The **digestive tube** (alimentary canal), about 9 metres long, extends from the mouth to the anus, and is lined throughout by mucous membrane. It consists of the following parts: at its commencement is the *mouth*, where provision is made for the mechanical division of the food (*mastication*), and for its admixture with a fluid secreted by the salivary glands (*insalivation*); beyond this are the organs of deglutition, the *pharynx* and the *œsophagus*, which convey the food into the *stomach*, where the first stages of the digestive process take place; the stomach is followed by the *small intestine*, which consists of three parts, the *duodenum*, the *jejunum*, and *ileum*. In the small intestine the process of digestion is completed and the resulting products are absorbed into the blood- and lymph-vessels. Finally the small intestine

is best evacuated from the tonsil by Hilton's method. Another form of acute inflammation of the tonsil is follicular tonsillitis, due to the lodgment of micro-organisms in the crypts of the tonsil. The removal of enlarged tonsils from children is, as a rule, a very simple operation, and is not usually attended with much hæmorrhage, unless the patient is suffering from hæmophilia. In the operation of 'enucleation' of the tonsil, advantage is taken of the fact that its deep surface is encapsuled, the entire tonsil and the capsule being removed.

The **palatine aponeurosis.**—Attached to the posterior border of the hard palate is a thin, firm fibrous lamella, the *palatine aponeurosis*, which supports the muscles and gives strength to the soft palate. It is thick above, but very thin and difficult to define below. On each side it is continuous with the tendon of the Tensor veli palatini.

Blakeway * maintains that the palatine aponeurosis is not a separate structure, but is actually the expanded tendon of the Tensor veli palatini.

The **muscles of the palate and fauces** (fig. 1081) are:

Levator veli palatini.	Glossopalatinus.
Tensor veli palatini.	Pharyngopalatinus.
Musculus uvulæ.	

The **Levator veli palatini** (Levator palati) is a rounded muscle situated on the lateral side of the choana. It arises from the under surface of the petrous part of the temporal bone, immediately in front of the lower opening of the carotid canal, and from the medial lamina of the cartilage of the auditory tube. After passing above the upper concave margin of the Constrictor pharyngis superior, and in front of the Salpingopharyngeus, it spreads out in the soft palate, its fibres running as far as the middle line, where they blend with those of the opposite muscle.

Nerve-supply.—The Levator veli palatini is supplied by the accessory cerebral nerve through the pharyngeal plexus.

Action.—The Levator veli palatini elevates the soft palate.

The **Tensor veli palatini** (Tensor palati) is a thin muscle placed on the lateral side of the Levator veli palatini and the medial pterygoid lamina of the sphenoidal bone. It arises by a flat lamella from the scaphoid fossa, from the medial surface of the spina angularis of the sphenoidal bone, and from the lateral lamina of the cartilage of the auditory tube. Descending vertically as far as the lower end of the medial pterygoid lamina, it ends in a tendon which turns medialwards below the pterygoid hamulus, and is inserted into the palatine aponeurosis and into the surface behind the transverse ridge on the horizontal part of the palatine bone. Between the tendon and the pterygoid hamulus there is a small bursa.

Nerve-supply.—The Tensor veli palatini is supplied by the mandibular nerve by twigs which traverse the otic ganglion.

Actions.—Acting singly the Tensor veli palatini pulls the soft palate to one side; acting together the two muscles will tighten the soft palate.

The **Musculus uvulæ** (Azygos uvulæ) arises from the posterior nasal spine of the palatine bones and from the palatine aponeurosis; it descends to be inserted into the uvula.

Nerve-supply.—The Musculus uvulæ is supplied by the accessory cerebral nerve through the pharyngeal plexus.

Action.—The Musculus uvulæ pulls up the uvula on its own side.

The **Glossopalatinus** (Palatoglossus) is a small fleshy fasciculus, narrower in the middle than at the ends, forming, with the mucous membrane covering its surface, the glossopalatine arch. It arises from the anterior surface of the soft palate, where it is continuous with the muscle of the opposite side, and passing downwards, forwards, and lateralwards in front of the palatine tonsil, is inserted into the side of the tongue, some of its fibres spreading over the dorsum of the tongue, and others passing deeply into its substance to intermingle with the Transversus linguæ.

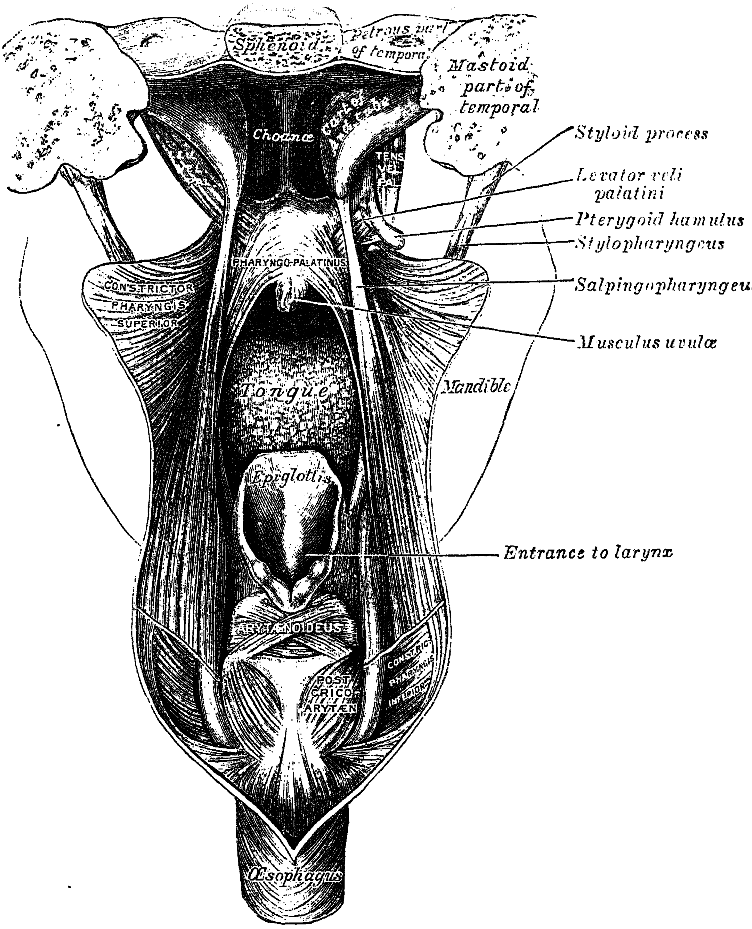
Nerve-supply.—The Glossopalatinus is supplied by the accessory cerebral nerve through the pharyngeal plexus.

* *Journal of Anatomy and Physiology*, vol. xlviii.

Actions.—The Glossopalatinus pulls up the root of the tongue and approximates the Glossopalatine arch to the median line.

The **Pharyngopalatinus** (Palatopharyngeus) is a long, fleshy fasciculus, forming, with the mucous membrane covering its surface, the pharyngopalatine arch. It is separated from the Glossopalatinus by the sinus tonsillaris, in which the palatine tonsil is lodged. It arises from the soft palate, where it is divided into two fasciculi by the Levator veli palatini and Musculus uvulæ. The *posterior fasciculus* is in contact with the mucous membrane covering the

Fig. 1081.—The muscles of the palate. Exposed from behind.



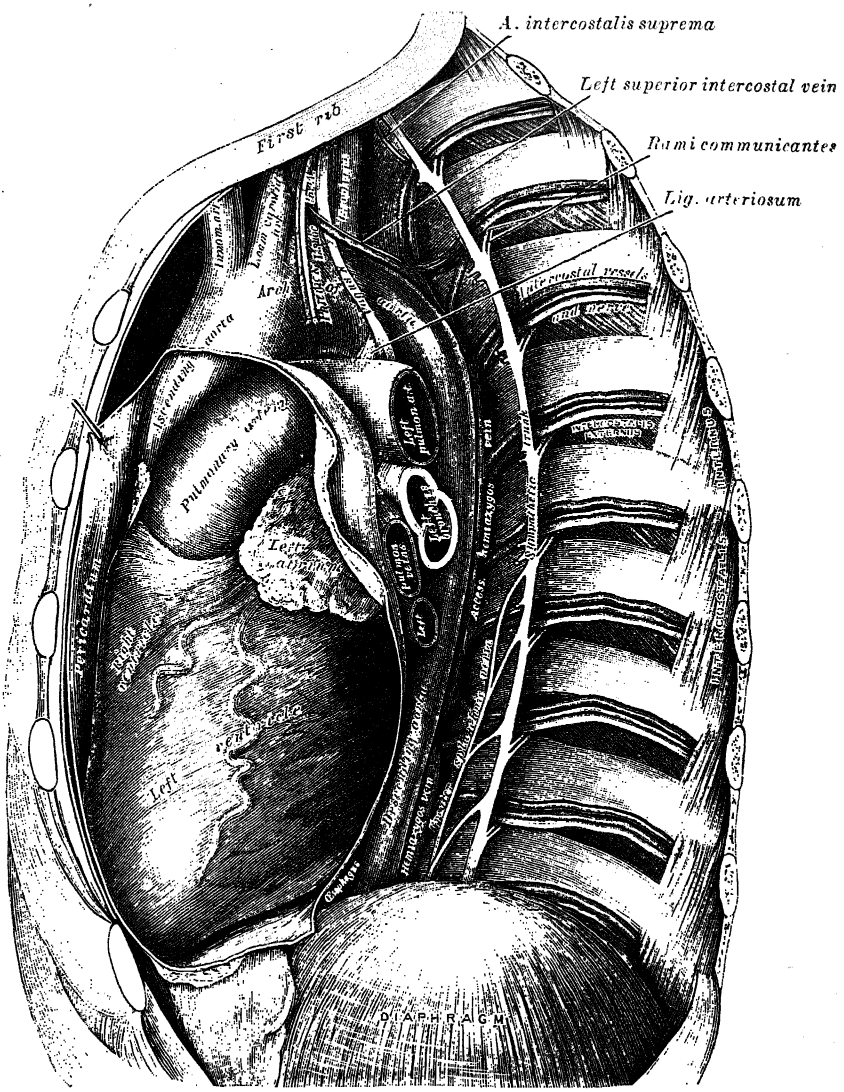
posterior surface of the palate; it joins with the posterior fasciculus of the opposite muscle in the middle line. The *anterior fasciculus*, the thicker, lies between the Levator veli palatini and the Tensor veli palatini, and joins, in the middle line, the anterior fasciculus of the opposite muscle. Passing lateralwards and downwards behind the palatine tonsil, the Pharyngopalatinus unites with the Stylopharyngeus, and is inserted with it into the posterior border of the thyreoid cartilage, some of its fibres ending on the side of the pharynx, and others passing across the middle line posteriorly, to decussate with the muscle of the opposite side.

Nerve-supply.—The Pharyngopalatinus is supplied by the accessory cerebral nerve through the pharyngeal plexus.

Actions.—The Pharyngopalatinus pulls the wall of the pharynx, on its own side, upwards, forwards and medialwards.

The **middle mediastinal cavity** (figs. 1042, 1043) is the broadest part of the interpleural space. It contains the heart enclosed in the pericardium, the ascending aorta, the lower half of the superior vena cava, the terminal part of the azygos vein, the bifurcation of the trachea, the two bronchi, the

FIG. 1044.—The superior, middle and posterior mediastinal cavities. Left lateral aspect.

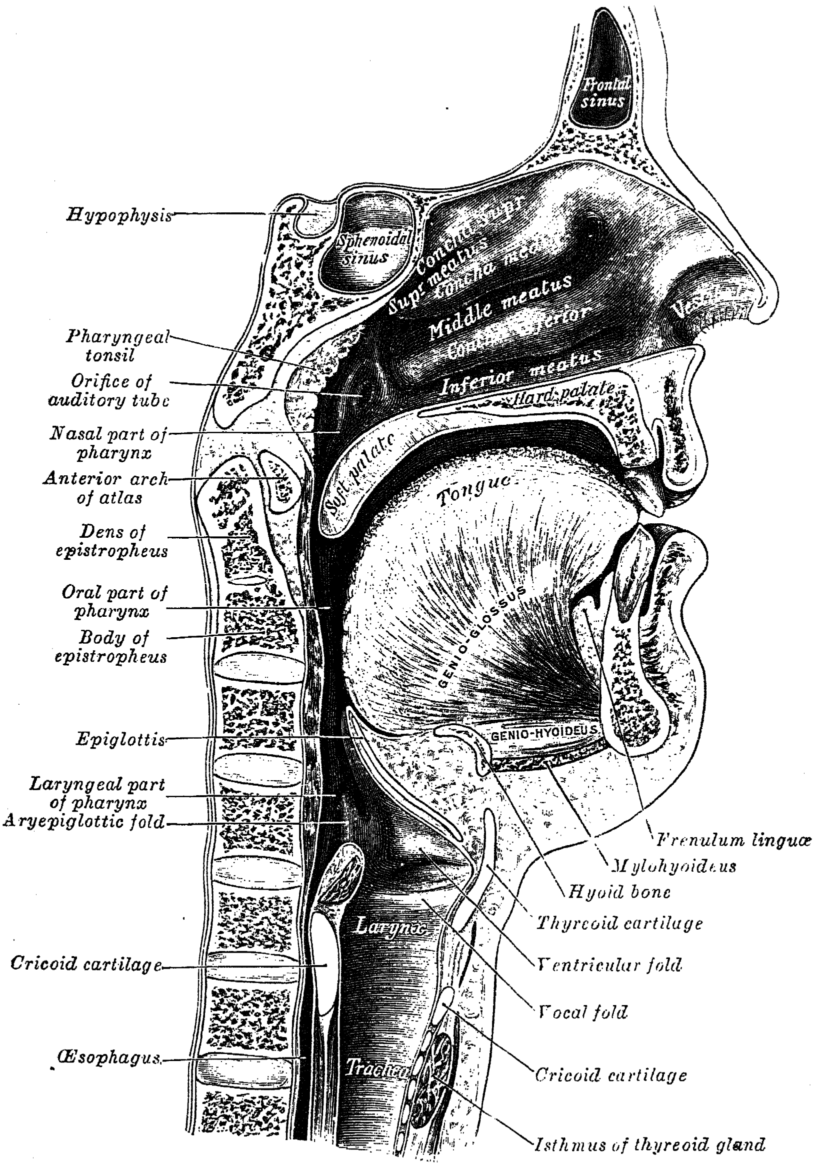


pulmonary artery dividing into its right and left branches, the right and left pulmonary veins, the phrenic nerves, and some tracheobronchial lymph-glands.

The **posterior mediastinal cavity** (figs. 1041, 1043) is an irregularly shaped space running parallel with the vertebral column ; it is bounded in front by the pericardium above, and by the posterior surface of the Diaphragm below, behind by the vertebral column from the lower border of the fourth to the twelfth thoracic vertebra, and on either side by the mediastinal pleura. It contains the thoracic part of the descending aorta, the azygos, hemiazygos, and accessory hemiazygos veins, the vagus and splanchnic nerves, the œsophagus, the thoracic duct, and some lymph-glands.

tubarius or *cushion*, caused by the pharyngeal end of the cartilage of the auditory tube which elevates the mucous membrane. A vertical fold of mucous membrane, the *salpingopharyngeal fold*, stretches from the lower part of the torus tubarius to the wall of the pharynx ; it contains the Salpingopharyngeus muscle.

FIG. 1082.—A sagittal section through the nose, mouth, pharynx and larynx.



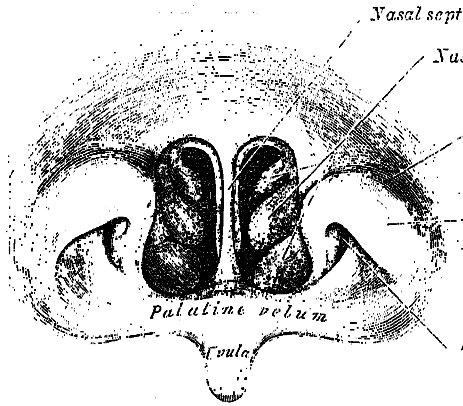
A second and smaller fold, the *salpingopalatine fold*, stretches from the upper part of the torus to the palate. Behind the torus is a deep recess, the *pharyngeal recess* or *fossa of Rosenmüller*. On the posterior wall between the pharyngeal recesses is a mass of lymphoid tissue, which is known as the *pharyngeal tonsil*, and is best developed in childhood.

The pharyngeal tonsil is visible to the naked eye during the later months of fœtal life and usually increases in size up to the age of six or seven years, after which it not infrequently begins to atrophy. In a child of eighteen months it forms a triangular prominence

the apex of which is near the nasal septum, and the base at the junction of the roof and posterior wall of the nasal part of the pharynx. The prominence consists of a number of folds which radiate forwards and lateralwards from a median recess, the *pharyngeal bursa*. The folds consist mainly of diffuse adenoid tissue, but there are also some deeply placed mucous glands. The pharyngeal bursa lies close to the base of the tonsil and presents the appearance of a blind recess.*

The **oral part of the pharynx** reaches from the soft palate to the level of the hyoid bone. It opens anteriorly, through the isthmus faucium, into the mouth, while in each of its lateral walls is the elevation of the pharyngopalatine arch (posterior pillar of the fauces) produced by the pharyngopalatine muscle (p. 1121). Between the glossopalatine arch in front and the pharyngopalatine arch behind there is a triangular recess in which the palatine tonsil is lodged (p. 1118).

Fig. 1083.—The front of the nasal part of the pharynx, as seen with the laryngoscope.



The **laryngeal part of the pharynx** reaches from the hyoid bone to the lower border of the cricoid cartilage, where it is continuous with the œsophagus. In the upper part of its anterior wall is the triangular entrance to the larynx (p. 1066); the base of the triangle is in front, and is formed by the epiglottis, while its sides are constituted by the aryepiglottic folds. On either side of the laryngeal orifice is a recess, the *recessus piriformis*, bounded medially by the aryepiglottic fold, and laterally by the thyreoid cartilage and hyothyreoid membrane.

Structure.—The pharynx is composed, from within outwards, of three coats: mucous, fibrous and muscular, the last being covered by the thin buccopharyngeal fascia (p. 448).

The *mucous coat* is continuous with that of the auditory tubes, nasal cavities, mouth, and larynx. In the nasal part of the pharynx its epithelium is columnar and ciliated; in the oral and laryngeal portions it is stratified squamous. Between the region covered by ciliated columnar epithelium and that covered by squamous epithelium, there is a narrow intermediate zone where the epithelium is cubical, and the cilia are imperfect or absent. Superiorly, this zone lies near the nasal septum: laterally it passes over the orifice of the auditory tube and inclines backwards at the union of the soft palate with the lateral wall. Racemose glands are found beneath the mucous membrane, and are especially numerous at the upper part of the pharynx around the orifices of the auditory tubes.

The *fibrous coat* is situated between the mucous and muscular layers. It is thick above (pharyngobasilar fascia) where the muscular fibres are wanting, and is firmly connected to the basilar portion of the occipital bone and the petrous portions of the temporal bones. As it descends it diminishes in thickness, and is gradually lost. It is strengthened posteriorly by a strong fibrous band, which is attached above to the pharyngeal tubercle on the under surface of the basilar portion of the occipital bone, and passes downwards as a median raphe which gives attachment to the Constrictores pharyngis.

The *muscular coat* consists of the muscles of the pharynx.

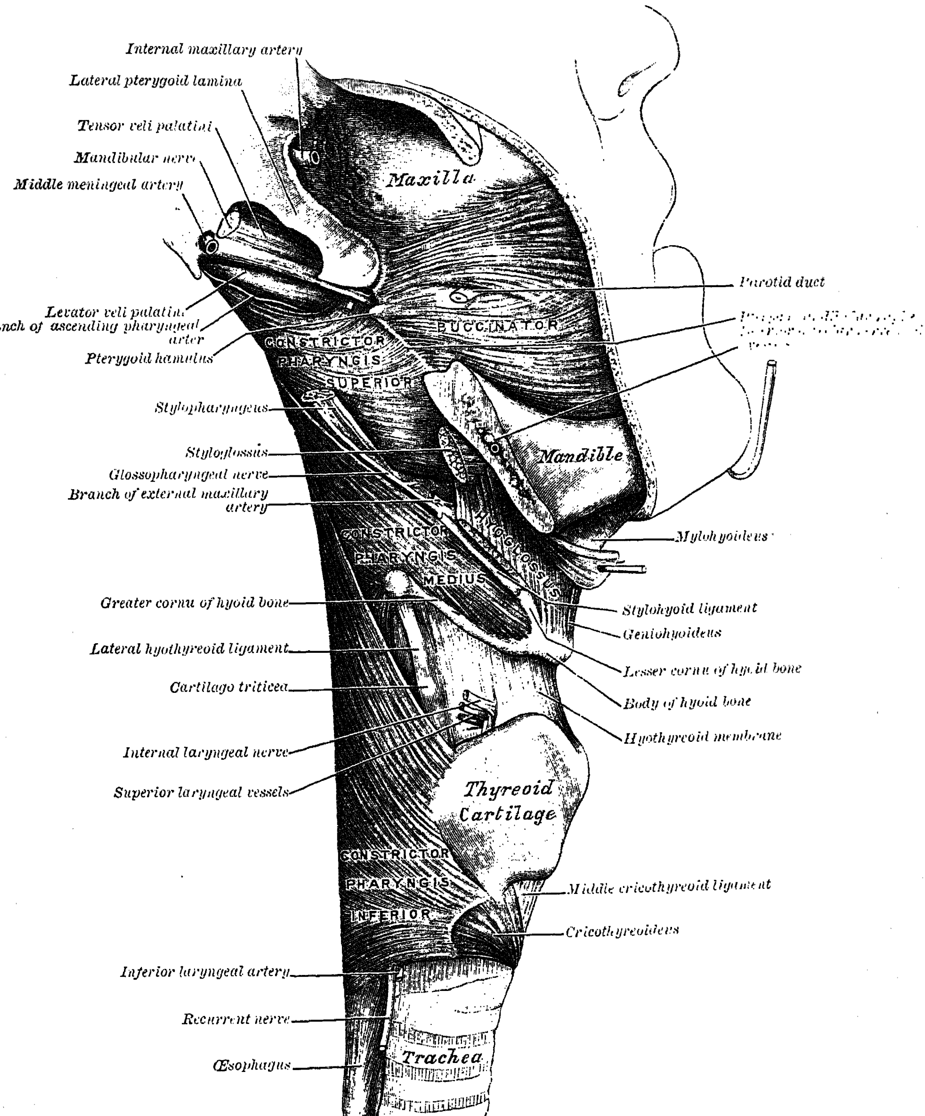
* J. Symington, *British Medical Journal*, Oct. 15, 1910.

The muscles of the pharynx (fig. 1084) are:

Constrictor pharyngis inferior.	Stylopharyngeus.
Constrictor pharyngis medius.	Salpingopharyngeus.
Constrictor pharyngis superior.	Pharyngopalatinus.*

The **Constrictor pharyngis inferior** is the thickest of the constrictors. It arises from the cricoid cartilage in the interval between the origin of the

FIG. 1084.—The Buccinator and the muscles of the pharynx.



Cricothyreoideus in front, and the articular facet for the inferior cornu of the thyreoid cartilage behind. It also arises from the oblique line on the lamina of the thyreoid cartilage, from the surface of the lamina behind this line nearly as far as the posterior border, and from the inferior cornu. The fibres spread backwards and medialwards, and are inserted with the muscle of the opposite side into a fibrous raphe in the posterior median line of the pharynx. The

* The Pharyngopalatinus is described with the muscles of the palate (p. 1121).

inferior fibres are horizontal and continuous with the circular fibres of the œsophagus; the rest ascend obliquely, and overlap the Constrictor medius.

Relations.—The Constrictor pharyngis inferior is covered by the buccopharyngeal fascia (p. 448) which surrounds the entire pharynx. *Behind*, the muscle is in relation with the prevertebral fascia and muscles; *laterally*, with the thyreoid gland, the common carotid artery, and the Sternothyreoideus; by its *internal surface*, with the Constrictor pharyngis medius, the Stylopharyngeus, the Pharyngopalatinus and the pharyngeal aponeurosis. The internal branch of the superior laryngeal nerve and the laryngeal branch of the superior thyreoid artery run near the upper border, and the recurrent nerve and the laryngeal branch of the inferior thyreoid artery ascend beneath its lower border, before they enter the larynx.

The **Constrictor pharyngis medius** is a fan-shaped muscle which arises from the lesser cornu, and from the whole length of the upper border of the greater cornu of the hyoid bone, and from the lower part of the stylohyoid ligament. The lower fibres descend beneath the Constrictor inferior, as far as the inferior end of the pharynx, the middle fibres pass transversely, and the upper fibres ascend and overlap the Constrictor superior. It is inserted, with the muscle of the opposite side, into the posterior median fibrous raphe.

Relations.—The Constrictor pharyngis medius is separated from the Constrictor pharyngis superior by the Stylopharyngeus muscle; and from the Constrictor pharyngis inferior by the internal branch of the superior laryngeal nerve and laryngeal branch of the superior thyreoid artery. *Behind* it are the prevertebral fascia, the Longus colli, and the Longus capitis. *Laterally* it is in relation with the carotid vessels, the pharyngeal plexus of nerves, and some lymph-glands. Near its origin it is covered by the Hyoglossus, from which it is separated by the lingual vessels. Its *internal surface* lies upon the Constrictor pharyngis superior, the Stylopharyngeus, the Pharyngopalatinus and the pharyngeal aponeurosis.

The **Constrictor pharyngis superior** is a quadrilateral muscle, thinner and paler than the other two. It arises from the lower one-third of the posterior margin of the medial pterygoid lamina and its hamulus, from the pterygomandibular raphe, from the posterior end of the mylohyoid line on the inner surface of the mandible, and by a few fibres from the side of the tongue. The fibres curve backwards to be inserted into the median raphe, being also prolonged by means of an aponeurosis to the pharyngeal tubercle on the basilar part of the occipital bone. The superior fibres arch beneath the Levator veli palatini and the auditory tube. The interval between the upper border of the muscle and the base of the skull is closed by the pharyngobasilar fascia (p. 1124) (pharyngeal aponeurosis), and is known as the *sinus of Morgagni*.

Relations.—The Constrictor pharyngis superior is in relation by its *external surface* with the prevertebral fascia and muscles, the internal carotid and ascending pharyngeal arteries, the internal jugular vein and pharyngeal venous plexus, the glossopharyngeal, vagus, hypoglossal and lingual nerves, the sympathetic trunks, the Constrictor pharyngis medius and Pterygoideus internus, the styloid process, the stylohyoid ligament, and the Stylopharyngeus. By its *internal surface* it is in relation with the Pharyngopalatinus, the capsule of the palatine tonsil and the pharyngeal aponeurosis. Its *upper border* is separated from the base of the skull by a crescentic interval in which the Levator veli palatini, the Tensor veli palatini and the auditory tube are situated. Its lower border is separated from the Constrictor pharyngis medius by the Stylopharyngeus. *In front* it is separated from the Buccinator by the pterygomandibular raphe.

Nerve-supply.—The Constrictores pharyngis inferior, medius et superior, are supplied by the pharyngeal plexus. The Constrictor pharyngis inferior receives also branches from the external laryngeal and recurrent nerves.

Actions.—During the process of swallowing, as soon as the bolus of food is received in the pharynx, the elevators of the pharynx relax, the pharynx descends, and the Constrictores contract upon the bolus and convey it downwards into the œsophagus.

The **Stylopharyngeus** (figs. 1078, 1084) is a long, slender muscle which is cylindrical above and flattened below. It arises from the medial side of the base of the styloid process of the temporal bone, descends along the side of the pharynx between the Constrictor pharyngis superior and the Constrictor pharyngis medius, and spreads out beneath the mucous membrane. Some of

its fibres are lost in the constrictor muscles, while others are inserted with the Pharyngopalatinus into the posterior border of the thyreoid cartilage. The glossopharyngeal nerve winds round the lateral side of this muscle to reach the tongue.

Nerve-supply.—The Stylopharyngeus is supplied by a branch from the glossopharyngeal nerve.

Actions.—The Stylopharyngeus draws the side of the pharynx upwards and lateralwards, thus increasing the transverse diameter of the pharynx.

The **Salpingopharyngeus** (fig. 1081) arises from the inferior part of the cartilage of the auditory tube near its pharyngeal orifice; it passes downwards and blends with the posterior fasciculus of the Pharyngopalatinus.

Nerve-supply.—The Salpingopharyngeus is supplied by the pharyngeal plexus.

Actions.—The Salpingopharyngeus raises the upper part of the lateral wall of the pharynx, i.e. the part above the attachment of the Stylopharyngeus.

Applied Anatomy.—In young children the presence of adenoid growths in the nose and nasopharynx, with or without enlargement of the tonsils, produces a characteristic deformity of the face, the "adenoid facies," by obstructing respiration through the nose and making mouth-breathing more or less obligatory. As the child has to keep its mouth open in order to breathe, the bony palate and alveolar arch are habitually out of contact with the dorsum of the tongue; lacking its pressure, they develop with an abnormally high arch and forward projection. Thus the hard palate becomes narrowed laterally, and the projecting alveolar processes afford insufficient room for the permanent teeth, which appear crowded, irregularly set, and overlapping as the child grows up, and overhang those in the lower jaw. The facial surfaces of the maxillæ become pinched together, with narrowing of the nasal fossæ and maxillary air-sinuses. The nose itself shows abnormality in shape of two chief types: (1) The bridge remaining normal, the apex looks thin and pinched because the alæ fall inwards from disuse of the dilator muscles, and the nares become elongated, narrow, and barely capable of voluntary dilatation; there is often a depression in the region of the lateral alar cartilage. (2) Less commonly the bones forming the bridge of the nose are pressed apart by the underlying adenoid growths, making it appear thicker and broader than normal; the Dilatatores narium atrophy from disuse, and the nares look unduly small and rounded. In all cases of adenoids the upper lip is drawn up, still further exposing the projecting front upper teeth. The face is lengthened by dropping of the lower jaw; the whole expression of the child is highly characteristic, suggesting vacuity and inattention, the latter being due to the deafness so often associated with nasal obstruction and caused by blocking of the pharyngeal orifices of the auditory tubes.

The internal carotid artery is in close relation with the pharynx, so that its pulsations can be felt through the mouth. It has been occasionally wounded by sharp-pointed instruments, introduced into the mouth and thrust through the wall of the pharynx. In aneurysm of this vessel in the neck, the tumour necessarily bulges into the pharynx, as this is the direction in which it meets with the least resistance, nothing lying between the vessel and the mucous membrane except the thin Constrictor muscles, whereas on the lateral side there are the dense cervical fascia, the muscles descending from the styloid process, and the margin of the Sternocleidomastoideus.

The mucous membrane of the pharynx is very vascular, and is often the seat of inflammation, frequently of a septic character, since the numerous recesses are prone to lodge micro-organisms. And, in addition, owing to its exposed situation, the mucous membrane is liable to be irritated by agents introduced during inspiration. The inflammation may be attended with serious consequences: it may extend up the auditory tube and involve the middle ear; it may spread to the entrance of the larynx, causing œdema and seriously interfering with respiration; or, invading the lymphatics, it may spread to the loose areolar tissue surrounding the pharyngeal wall, and may extend far and wide, sometimes into the posterior mediastinal cavity along the œsophagus. Abscess may form in the connective tissue behind the pharynx, between it and the vertebral column, constituting what is known as *retropharyngeal abscess.* Acute retropharyngeal abscesses are generally due to suppuration of the lymph-glands, and should be opened through the mouth, as the pus is in front of the prevertebral fascia. Chronic retropharyngeal abscesses are generally due to disease of the upper cervical vertebræ, and the pus is then behind the prevertebral fascia; the incision should therefore be made at the posterior border of the Sternocleidomastoideus, and the pus evacuated behind the carotid vessels.

Abscess also occurs in children, underneath the mucous membrane, between it and the pharyngeal aponeurosis. The condition usually arises from a peritonsillar inflammation, which spreads backwards. In some cases an enormous swelling may form, which pushes forwards the soft palate and gives rise to respiratory obstruction. In such cases the abscess should be opened through the mouth with the child in the inverted position, so as to prevent the first gush of pus from entering the larynx.

Foreign bodies not infrequently become lodged in the pharynx, and most usually at its termination at about the level of the cricoid cartilage, just beyond the reach of the finger, as the distance from the arch of the teeth to the commencement of the œsophagus is about 15 cm.

The Œsophagus (fig. 1085)

The **œsophagus**, or **gullet**, is a muscular canal, from 23 cm. to 25 cm. long, extending from the pharynx to the stomach. It begins in the neck at the lower border of the cricoid cartilage, opposite the sixth cervical vertebra, where it is continuous with the lower end of the pharynx. It descends along the front of the vertebral column, through the superior and posterior mediastinal cavities, pierces the Diaphragm opposite the tenth thoracic vertebra, and ends at the cardiac orifice of the stomach at the level of the eleventh thoracic vertebra. The general direction of the œsophagus is vertical; but it presents two slight curves in its course. At its commencement it is placed in the middle line; but it inclines to the left side as far as the root of the neck, gradually passes again to the middle line, which it reaches at the level of the fifth thoracic vertebra, and again deviates to the left as it passes forwards to the œsophageal hiatus in the Diaphragm. The œsophagus also presents anteroposterior flexures corresponding to the curvatures of the cervical and thoracic portions of the vertebral column. It is the narrowest part of the digestive tube, and is constricted (*a*) at its commencement, (*b*) where it is crossed by the left bronchus, and (*c*) where it pierces the Diaphragm.

Fig. 1085.—The œsophagus.

Relations.—The **cervical portion** of the œsophagus (fig. 1034) is in relation, *in front*, with the trachea, and at the lower part of the neck, where it projects to the left side, with the thyreoid gland; *behind* it are the vertebral column and Longus colli muscles; *on either side* it is in relation with the common carotid artery (especially the left), and parts of the lobes of the thyreoid gland; the recurrent nerves ascend, one on either side, in the groove between it and the trachea; to its left side is the thoracic duct.

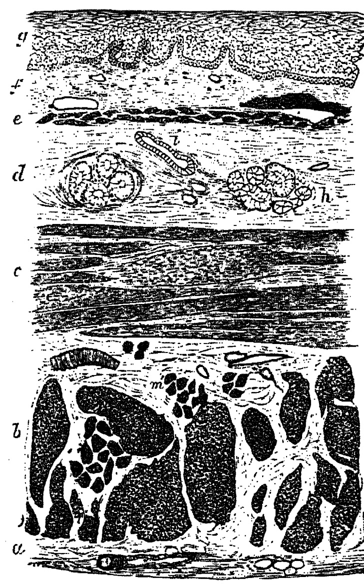
The **thoracic portion** of the œsophagus (figs. 1035-6, 1042-3, 1045) is at first situated in the superior mediastinal cavity between the trachea and the vertebral column, a little to the left of the median line. It then passes behind and to the right of the aortic arch and descends in the posterior mediastinal

cavity, along the right side of the descending aorta, then runs in front and a little to the left of the aorta, and enters the abdomen through the Diaphragm at the level of the tenth thoracic vertebra. It is in relation, *in front*, with the trachea, the left bronchus, the pericardium, and the Diaphragm; *behind*, it rests upon the vertebral column, the Longus colli muscles, the right aortic intercostal arteries, the thoracic duct, and the hemiazygos and accessory hemiazygos veins; and below, near the Diaphragm, upon the front of the aorta. On its *left* side, in the superior mediastinal cavity are the terminal part of the aortic arch, the left subclavian artery, the thoracic duct, and left pleura, while running upwards in the groove between it and the trachea is the left recurrent nerve; below, it is in relation with the descending thoracic aorta and the left pleura. On its *right* side are the right pleura, and the azygos vein, the latter being overlapped by the œsophagus. Below the roots of the lungs the vagus nerves descend in close contact with it, the right nerve behind, and the left in front of it; the two nerves unite to form a plexus around the tube.

In the lower part of the posterior mediastinal cavity the thoracic duct lies behind and to the right of the œsophagus; higher up, it is placed behind it, and crossing to the left about the level of the fourth thoracic vertebra, is continued upwards on its left side.

The **abdominal portion** of the œsophagus is named the *antrum cardiacum*; it lies in the œsophageal groove on the posterior surface of the left lobe of the liver. It measures about 1·25 cm. in length, and is covered by peritoneum in front and on its left side. It is conical in shape, and curved sharply to the left, the base of the cone being continuous with the cardiac orifice of the stomach (fig. 1085).

Fig. 1086.—A transverse section through the middle of the œsophagus. (From a drawing by V. Horsley.) Moderately magnified. (From Quain's Elements of Anatomy, Vol. II. Pt. II.)



a. Fibrous covering. *b.* Divided fibres of longitudinal muscular coat. *c.* Transverse muscular fibres. *d.* Submucous or areolar layer. *e.* Muscularis mucosæ. *f.* Mucous membrane, with vessels and part of a lymphoid nodule. *g.* Stratified epithelial lining. *h.* Mucous gland. *l.* Gland duct. *m'.* Striated muscular fibres cut across.

Structure (fig. 1086).—The œsophagus has four coats: an external or fibrous, a muscular, a submucous or areolar, and an internal or mucous.

The *fibrous coat* consists of a layer of areolar tissue, containing many elastic fibres.

The *muscular coat* is composed of two layers of considerable thickness: an external of longitudinal and an internal of circular fibres.

The *longitudinal fibres* form a complete investment for nearly the whole of the œsophagus, but at the upper part of the back of the tube, at a point between 3 cm. and 4 cm. below the cricoid cartilage, they diverge from the middle line and form two longitudinal fasciculi which incline upwards and forwards to the front of the tube. Here they pass beneath the lower border of the Constrictor pharyngis inferior and end in a tendon, which is attached to the upper part of the ridge on the posterior surface of the lamina of the cricoid cartilage. The V-shaped interval between the diverging longitudinal fasciculi is filled by the circular fibres of the œsophagus, thinly covered below by some decussating longitudinal fibres, and above by the overlapping lower edge of the Constrictor pharyngis inferior.

Accessory slips of muscular fibres sometimes pass between the œsophagus and the left pleura, or between the œsophagus and the root of the left bronchus.

The *circular fibres* are continuous superiorly, on the posterior aspect, with the Constrictor pharyngis inferior; anteriorly, the uppermost are inserted into the lateral margins of the tendon of the two longitudinal fasciculi.*

The muscular fibres in the upper part of the œsophagus are of a red colour, and consist chiefly of the striped variety; but in the lower part they consist for the most part of involuntary fibres.

* Williamina Abel, *Journal of Anatomy and Physiology*, vol. xlvii.

The *areolar or submucous coat* connects loosely the mucous and muscular coats. It contains the larger blood-vessels and nerves, as well as mucous glands.

The *mucous coat* is thick, of a reddish colour above, and pale below. It is disposed in longitudinal folds, which disappear on distension of the tube. It consists of (1) a layer of stratified squamous epithelium, lining the tube, (2) a layer of connective tissue, papillæ from which project into the epithelium, and (3) the muscularis mucosæ, a layer of longitudinally arranged non-striped muscular fibres. At the commencement of the œsophagus the muscularis mucosæ is absent, or only represented by a few scattered bundles; lower down it forms a considerable stratum.

The *œsophageal glands* are small compound racemose glands of the mucous type; they are lodged in the submucous tissue, and each opens upon the surface by a long duct.

Vessels and Nerves.—The *arteries* supplying the œsophagus are derived from the inferior thyreoid branch of the thyreocervical trunk, from the descending thoracic aorta, from the left gastric branch of the cœliac artery, and from the left inferior phrenic branch of the abdominal aorta. They have for the most part a longitudinal direction. The *veins* from the lower end of the œsophagus open into the left gastric vein, which is a tributary of the portal vein. The *lymphatics* are described on p. 778.

The *nerves* are derived from the vagus nerves and from the sympathetic trunks; they form a plexus, in which are groups of ganglion-cells, between the two layers of the muscular coat, and a second plexus in the submucous tissue.

Applied Anatomy.—The œsophagus may be obstructed by foreign bodies, and also by changes in its coats producing stricture, or by pressure on it from without by new growths or aneurysm, &c. The commoner forms of stricture are: (1) the fibrous, due to cicatrisation following destruction of tissue, the result of swallowing boiling or corrosive fluids—here dilatation of the stricture may be carried out; and (2) malignant, usually epitheliomatous in its nature. This may be situated either at the upper end of the tube, opposite the cricoid cartilage, or at its lower end at the cardiac orifice, but is most commonly found in that part of the tube which is crossed by the left bronchus. If, in these cases, the patient is losing weight from insufficient nourishment, the operation of gastrostomy may be performed in order to avoid death from starvation; death, however, most commonly occurs from ulceration of the growth into the mediastinal cavity or air-passages. In cases of non-malignant stricture of the œsophagus it may be necessary to dilate the canal by a bougie, when it is of importance that the direction of the œsophagus and its relations to surrounding parts should be remembered. In malignant disease of the œsophagus, where its tissues have become softened from infiltration of the growth, the passage of a bougie is a very dangerous procedure, as a false passage may easily be made, and the instrument may pass into the mediastinal cavity or into one or other pleural cavity, or even into the pericardium.

In cases of obstruction of the œsophagus, and consequent symptoms of stricture, produced by an aneurysm of some part of the aorta pressing upon this tube, the passage of a bougie will only hasten the fatal issue, and therefore it is essential that the presence of an aneurysm should be excluded before such an attempt be made in any form of œsophageal obstruction.

In passing a bougie the left forefinger should be introduced into the mouth, and the epiglottis felt for, care being taken not to throw the head too far backwards. The bougie is then to be passed beyond the finger until it touches the posterior wall of the pharynx. The patient is now asked to swallow, and at the moment of swallowing, the bougie is passed gently onwards, any force being carefully avoided.

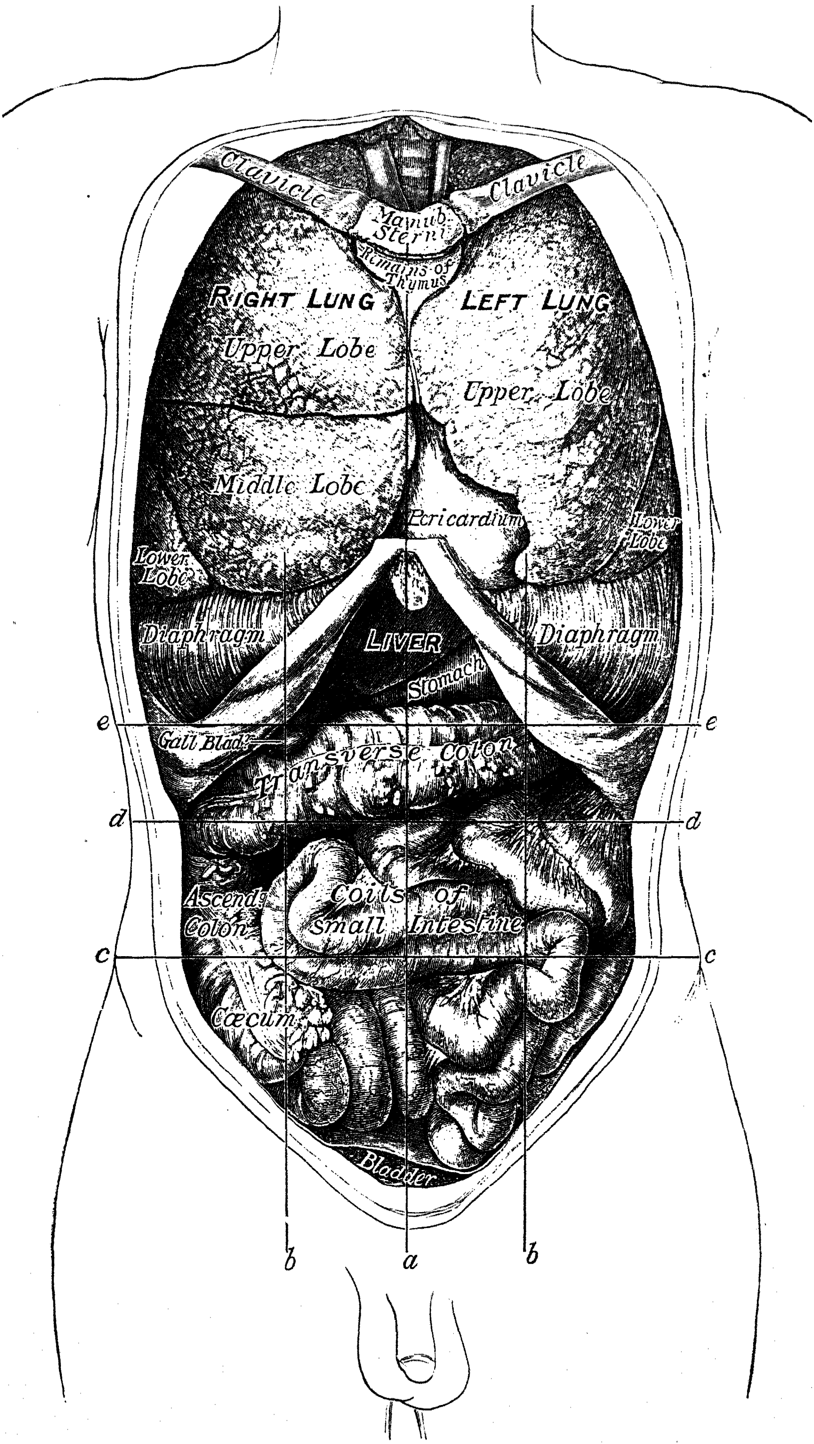
It occasionally happens that a foreign body becomes impacted in the œsophagus, and can neither be brought upwards nor moved downwards. When all ordinary means for its removal have failed, open operation by an incision in the neck is the only resource left. This, of course, can only be performed when the foreign body is not very low down. If it is allowed to remain, extensive inflammation and ulceration of the œsophagus may ensue, with the development of suppuration and cellulitis in the surrounding tissues.

THE ABDOMEN

The **abdomen** is the largest cavity in the body. The roof of the cavity is formed by the Diaphragm, which extends as a dome over the abdomen, so that the cavity ascends into the bony thorax, reaching on the right side, in the mammary line, to the upper border of the fifth rib; on the left side it falls below this level by about 2·5 cm. The floor is formed by the muscles and fasciæ of the pelvic and urogenital diaphragms (pp. 482-491).

In order to facilitate description the abdomen is artificially divided into two parts: an upper, larger part, the *abdomen proper*; and a lower, smaller part, the *pelvis*. These two parts are continuous with one another through the superior aperture of the lesser pelvis.

FIG. 1087.—A front view of the thoracic and abdominal viscera.



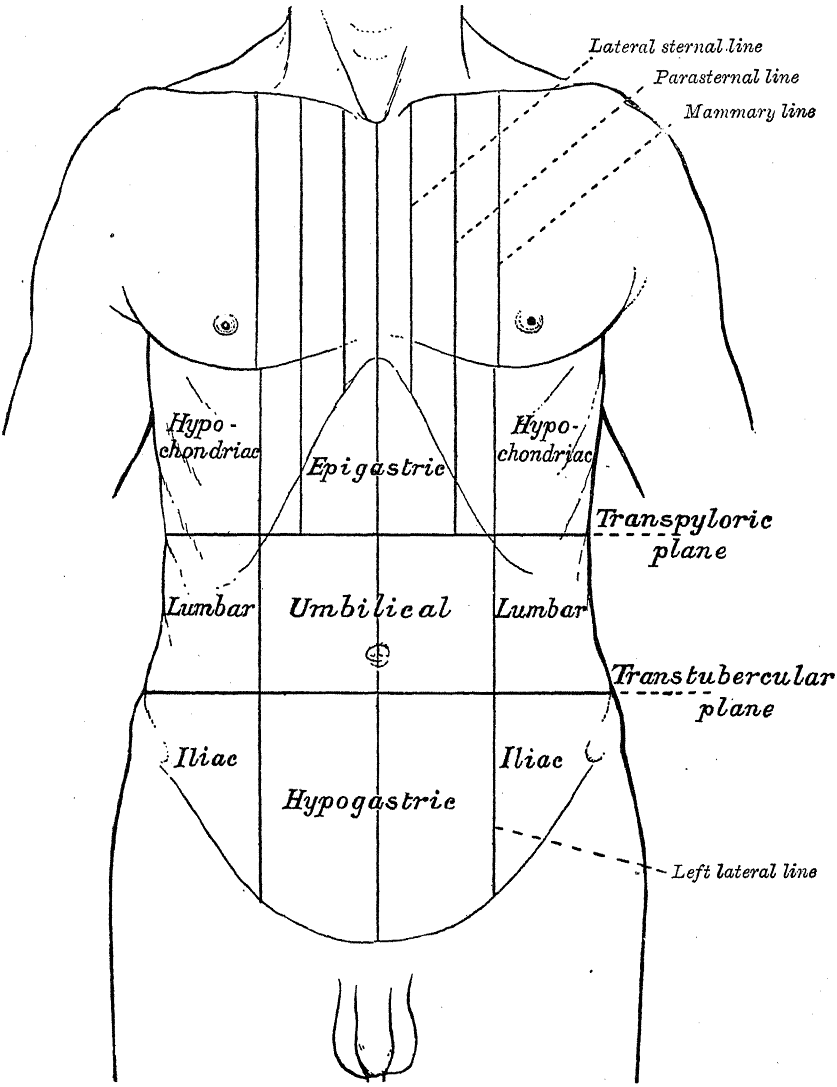
The greater omentum has been removed.

a. Median plane. *b b.* Lateral planes. *c c.* Transtubercular plane. *d d.* Subcostal plane. *e e.* Transpyloric plane.

The **abdomen proper** differs from the other cavities of the body in being bounded for the most part by muscles and fasciæ, so that its capacity and shape can vary according to the conditions of the viscera it contains.

It is bounded *in front* and *at the sides* by the abdominal and Iliacus muscles, and the iliac bones; *behind* by the lumbar part of the vertebral column and

FIG. 1088.—The surface lines on the front of the thorax and abdomen.



by the Psoas and Quadratus lumborum muscles; *above* by the Diaphragm; *below* by the plane of the superior aperture of the lesser pelvis. The muscles forming the boundaries of the cavity are lined upon their inner surfaces by a layer of fascia.

The abdomen contains the greater part of the digestive tube; it also contains the liver, pancreas, spleen, kidneys, and suprarenal glands. Most of these structures, as well as the wall of the cavity in which they are contained, are more or less covered by an extensive and complicated serous membrane, the *peritoneum*.

Regions.—For convenience of description of the viscera, as well as of reference to the morbid conditions of the contained parts, the abdomen is

divided into nine regions by imaginary planes, two horizontal and two sagittal, passing through the cavity, the edges of the planes being indicated by lines drawn on the surface of the body (fig. 1088). The upper horizontal plane, or *transpyloric plane* of Addison, is indicated by a line encircling the body at a level midway between the jugular notch and the symphysis pubis, the lower horizontal plane by a line carried round the trunk at a level midway between the transpyloric plane and the symphysis pubis. The latter plane is practically the same as the *transtubercular* or *intertubercular plane* of Cunningham, who pointed out * that its level corresponds with the prominent and easily defined tubercle on the iliac crest about 5 cm. behind the anterior superior iliac spine. By means of these planes the abdomen is cut into three zones; each of these is further subdivided into three regions by the two sagittal planes, which are indicated on the surface by lines drawn vertically through points halfway between the anterior superior iliac spines and the symphysis pubis.†

The middle region of the upper zone is the *epigastric*, and the lateral regions, the *right and left hypochondriac.* The central region of the middle zone is the *umbilical*, and the lateral regions are the *right and left lumbar.* The middle region of the lower zone is the *hypogastric*, and the lateral regions are the *right and left iliac or inguinal* (fig. 1088).

The **pelvis** is that portion of the abdominal cavity which lies below and behind a plane passing through the promontory of the sacrum, the arcuate lines of the hip-bones, and the pubic crests; it contains the urinary bladder, the sigmoid colon, the rectum, a few coils of the small intestine, and some of the generative organs.

When the anterior abdominal wall is removed, the viscera are partly exposed as follows: above and to the right side is the liver, situated chiefly under the shelter of the right ribs and their cartilages, but extending across the middle line and reaching for some distance below the level of the xiphoid process. To the left of the liver is the stomach, from the lower border of which an apron-like fold of peritoneum, the *greater omentum*, descends for a varying distance, and obscures, to a greater or lesser extent, the other viscera. Below the greater omentum, however, some of the coils of the small intestine can generally be seen, while in the right iliac region the cæcum, and in the left iliac region the iliac portion of the descending colon, are partly exposed. The urinary bladder occupies the anterior part of the pelvis, and, if distended, will project above the symphysis pubis; the rectum is placed in the concavity of the sacrum, but is usually obscured by coils of the small intestine. The sigmoid colon may lie between the rectum and the bladder.

When the stomach is followed from left to right it is seen to be continuous with the first part of the small intestine (duodenum), the point of continuity being marked by a thickened ring which indicates the position of the pyloric sphincter. The duodenum passes towards the under surface of the liver, and then, curving downwards, is lost to sight. If, however, the greater omentum and transverse colon be thrown upwards over the chest, the inferior part of the duodenum will be observed passing across the vertebral column towards the left side, where it becomes continuous with the coils of the jejunum and ileum. These measure about six metres in length, and if followed downwards the ileum is seen to end in the right iliac fossa by opening into the cæcum, the commencement of the large intestine. From the cæcum the large intestine takes an arched course, passing at first upwards on the right side, then across the middle line and downwards on the left side, and forming respectively the ascending, transverse, and descending parts of the colon. In the pelvis it assumes the form of a loop, termed the sigmoid colon, and ends in the rectum.

The spleen lies behind the stomach in the left hypochondriac region, and may be in part exposed by pulling the stomach over towards the right side.

The glistening appearance of the deep surface of the abdominal wall and of the surfaces of the exposed viscera is due to the fact that the former is lined, and the latter are more or less completely covered, with a serous membrane, the *peritoneum.*

* *Journal of Anatomy and Physiology*, vol. xxvii. † *Ibid.*, vols. xxxiii., xxxiv., xxxv.

The Peritoneum

The **peritoneum** is the largest serous membrane in the body, and consists, in the male, of a closed sac, a part of which is applied against the abdominal parietes, while the remainder is reflected over the contained viscera. In the female the free ends of the uterine tubes open into the peritoneal cavity. The portion which lines the parietes is named the *parietal* portion of the peritoneum; that which is reflected over the contained viscera constitutes the *visceral* portion of the peritoneum. The *free surface* of the membrane is smooth, covered with a layer of flattened endothelium, and lubricated by a small quantity of serous fluid. Hence the viscera can glide on the wall of the cavity or on one another with the least possible amount of friction. The *attached surface* is rough, being connected to the viscera and inner surface of the parietes by means of areolar tissue, termed the *subserous areolar tissue*. The parietal portion is loosely connected with the fascial lining of the abdomen and pelvis, but is more closely adherent to the under surface of the Diaphragm, and also in the middle line of the anterior abdominal wall.

The parietal and visceral layers of the peritoneum are in actual contact, but the potential space between them is named the *peritoneal cavity*. The peritoneal cavity consists of (1) a main portion, and (2) a large diverticulum, the *omental bursa*, which is situated behind the stomach and adjoining structures; the neck or communication between the main cavity and the omental bursa is termed the *epiploic foramen* (foramen of Winslow). Formerly the main portion of the cavity was described as the greater sac, and the omental bursa as the lesser sac, of the peritoneum.

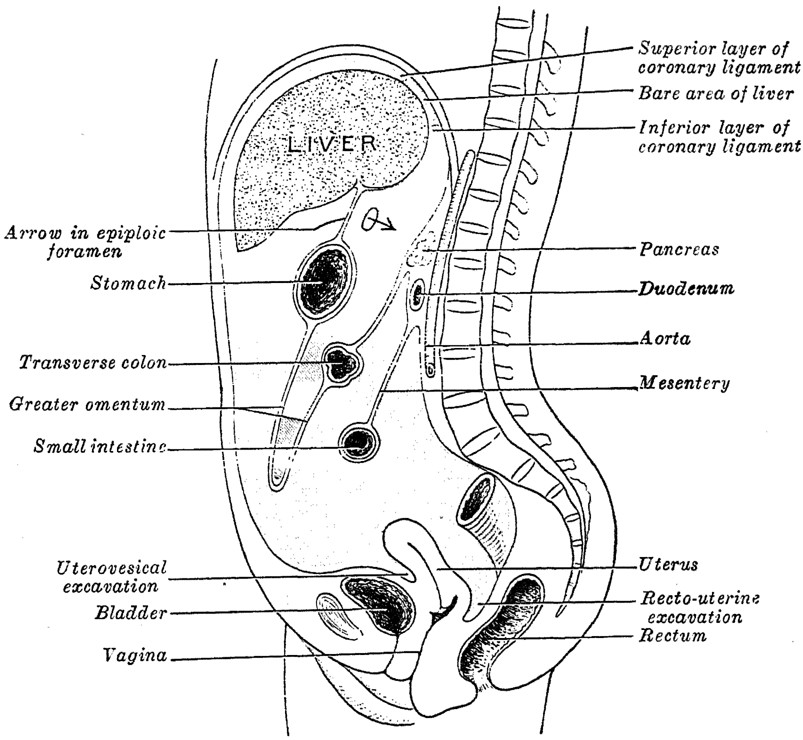
The peritoneum differs from the other serous membranes of the body in presenting a much more complex arrangement, and one that can only be clearly understood by following the development of the digestive tube. The student therefore is advised to preface his study of the peritoneum by reading the chapter dealing with this subject (p. 132).

To trace the membrane from one viscus to another, and from the viscera to the parietes, it is necessary to follow its continuity in the vertical and horizontal directions, and it will be found simpler to describe the main portion of the cavity and the omental bursa separately.

Vertical disposition of the main peritoneal cavity (greater sac) (fig. 1089).—It is convenient to trace this from the back of the anterior abdominal wall at the level of the umbilicus. On following the peritoneum upwards from this level it is seen to be reflected around a fibrous cord, the *ligamentum teres*, or *obliterated umbilical vein*, which reaches from the umbilicus to the under surface of the liver. This reflection forms a somewhat triangular fold, the *falciform ligament of the liver*, attaching the upper and anterior surfaces of the liver to the Diaphragm and abdominal wall. With the exception of the line of attachment of this ligament the peritoneum covers the whole of the under surface of the anterior part of the Diaphragm, and is reflected from it on to the upper surface of the right lobe of the liver as the *superior layer of the coronary ligament*, and on to the upper surface of the left lobe as the *superior layer of the left triangular ligament* of the liver. Covering the upper and anterior surfaces of the liver, it is continued round its sharp margin to the under surface, where it has the following relations: (*a*) It covers the inferior surface of the right lobe and is reflected from the posterior part of this lobe to the right suprarenal gland and the upper end of the right kidney, forming the *inferior layer of the coronary ligament*; a special fold, the *hepatorenal ligament*, is frequently present between the inferior surface of the liver and the front of the right kidney. From the right kidney it is carried downwards to the duodenum and right colic flexure and medialwards in front of the inferior vena cava, where it is continuous with the posterior wall of the omental bursa. Between the two layers of the coronary ligament there is a large triangular surface of the liver devoid of peritoneal covering: this is named the *bare area* of the liver, and is attached to the Diaphragm by areolar tissue. Towards the right margin of the liver the two layers of the coronary ligament gradually approach one another, and ultimately fuse to form a small triangular fold connecting the right lobe of the liver to the Diaphragm, and named the *right triangular ligament* of the liver. The apex of the bare area corresponds with the point of meeting

of the two layers of the coronary ligament, its base with the fossa for the inferior vena cava. (*b*) It covers the lower surface of the quadrate lobe of the liver, the under and lateral surfaces of the gall-bladder, and the under surface and posterior border of the left lobe of the liver ; it is then reflected from the upper surface of the left lobe to the Diaphragm as the *inferior layer of the left triangular ligament*, and from the porta of the liver and the fossa for the ductus venosus to the lesser curvature of the stomach and the first 2·5 cm. of the duodenum as the anterior layer of the *hepatogastric* and *hepatoduodenal ligaments*, which together constitute the *lesser omentum*. If this layer of the lesser omentum be followed to the right it will be found to turn round the hepatic artery, bile-duct, and portal vein, and become continuous with the anterior wall of

FIG. 1089.—The vertical disposition of the peritoneum. (Main cavity, red ; omental bursa, blue).

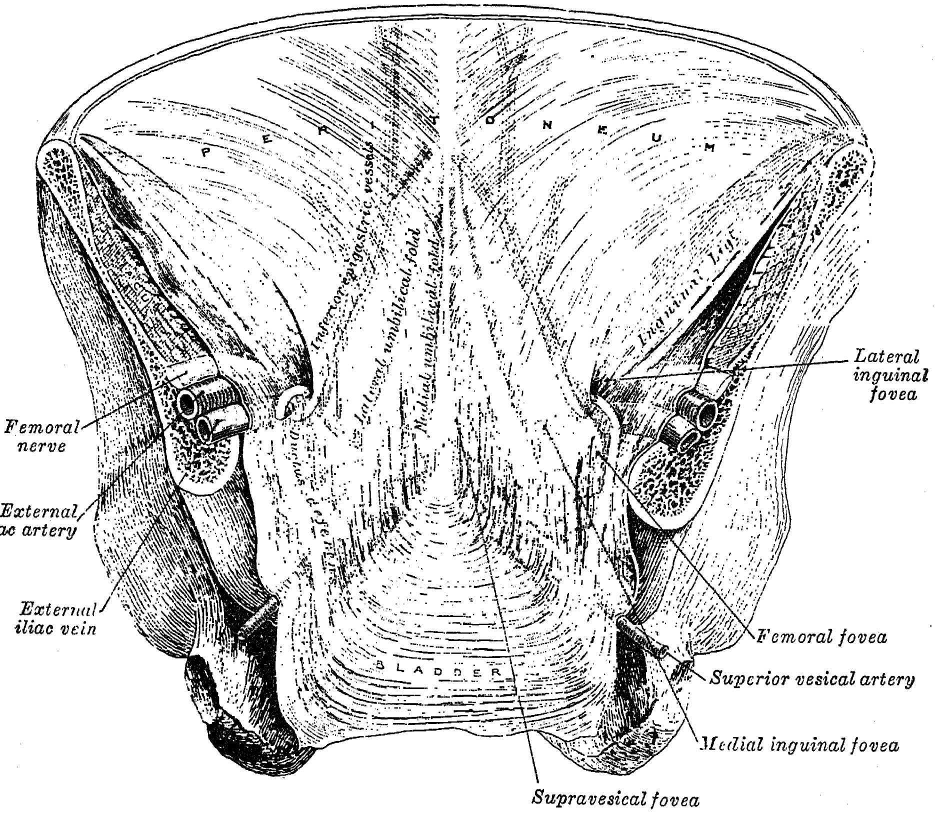


the omental bursa, forming a free folded edge of peritoneum. Traced downwards, the lesser omentum covers the anterosuperior surface of the stomach and the commencement of the duodenum, and is carried down into a large free fold, known as the *gastrocolic ligament* or *greater omentum*. Reaching the free margin of this fold, it is reflected upwards to cover the under and posterior surfaces of the transverse colon, and thence to the posterior abdominal wall as the inferior layer of the *transverse mesocolon*. It reaches the abdominal wall at the head and anterior border of the pancreas, is then carried down over the lower part of the head and over the inferior surface of the pancreas on the superior mesenteric vessels, and thence to the small intestine as the anterior layer of the *mesentery*. It encircles the intestine, and subsequently may be traced, as the posterior layer of the mesentery, upwards and backwards to the abdominal wall. From this it sweeps down over the aorta into the pelvis, where it invests the sigmoid (pelvic) colon, and attaches it to the pelvic wall by a fold named the *sigmoid mesocolon* (pelvic mesocolon). Leaving first the sides and then the front of the rectum, it is reflected on to the seminal vesicles and the fundus of the urinary bladder, and after covering the upper surface of that

viscus, is carried along the middle and lateral umbilical ligaments (fig. 1090) on to the back of the abdominal wall to the level from which a start was made.

Between the rectum and the bladder it forms, in the male, a pouch, the *rectovesical excavation*, the bottom of which is slightly below the level of the upper ends of the vesiculæ seminales, and about 7·5 cm. from the orifice of the anus. When the bladder is distended, the peritoneum is carried up with it so that a considerable part of the anterior surface of the bladder lies directly against the abdominal wall without the intervention of peritoneal membrane. In the female the peritoneum is reflected from the rectum over the posterior

Fig. 1090.—The lower part of the anterior abdominal wall. Posterior aspect. The peritoneum is in place, and the various cords are shining through. (After Joessel.)

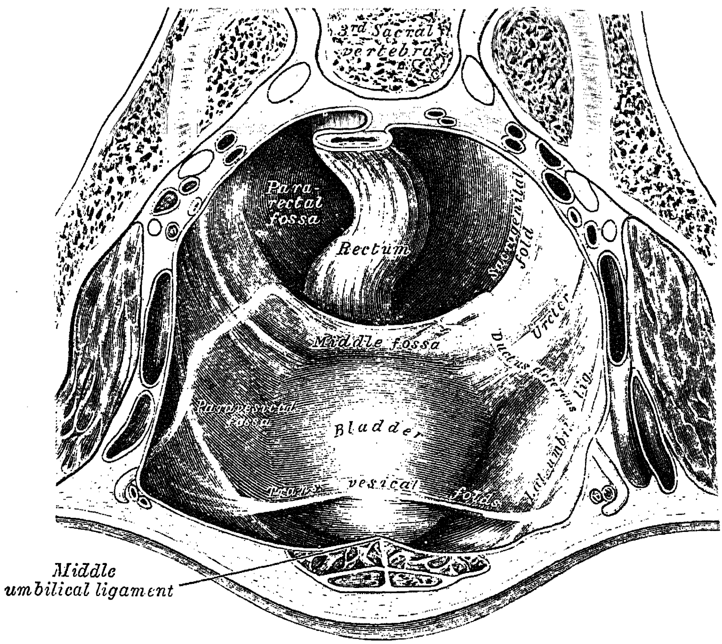


vaginal fornix to the cervix and body of the uterus, forming the *recto-uterine excavation* or *pouch of Douglas*. It is continued over the intestinal surface and fundus of the uterus on to its vesical surface, which it covers as far as the junction of the body and neck of the uterus, and then to the bladder, forming here a second, but shallower, pouch, the *vesico-uterine excavation*. It is also reflected from the sides of the uterus to the lateral walls of the pelvis as two expanded folds, the *broad ligaments of the uterus*, in the free margin of each of which is the uterine tube.

Vertical disposition of the omental bursa (lesser sac) (fig. 1089).—A start may be made in this case on the posterior abdominal wall at the anterior border of the pancreas. From this region the peritoneum may be followed upwards over the anterior surface of the pancreas to the inferior surface of the Diaphragm, and thence on the caudate lobe and caudate process of the liver to the fossa for the ductus venosus and the porta hepatis. Traced to the right, it is continuous over the inferior vena cava with the posterior wall of the main cavity. From the liver it is carried downwards to the lesser

curvature of the stomach and the commencement of the duodenum as the posterior layer of the lesser omentum, and is continuous on the right, round the hepatic artery, bile-duct, and portal vein, with the anterior layer of this omentum. The posterior layer of the lesser omentum is carried down as a covering for the postero-inferior surface of the stomach and commencement of the duodenum, and is continued downwards as the deep layer of the gastro-colic ligament or greater omentum. From the free margin of this fold it is reflected upwards to the anterior and superior surfaces of the transverse colon, and thence as the superior layer of the transverse mesocolon to the anterior border of the pancreas, the level from which a start was made. It will be seen that the loop formed by the wall of the omental bursa below the transverse colon follows, and is closely applied to, the deep surface of that formed by the peritoneum of the main cavity, and that the greater omentum or large fold of

FIG. 1091.—The peritoneum of the male pelvis. (Dixon and Birmingham.)



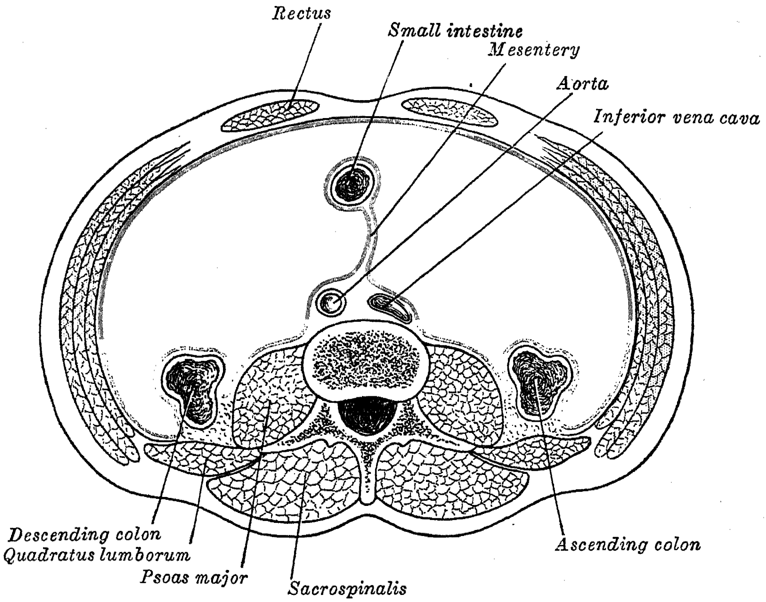
peritoneum which hangs in front of the small intestine therefore consists of four layers, two anterior and two posterior, separated by the potential cavity of the omental bursa. The transverse colon lies between the two posterior layers.

Horizontal disposition of the peritoneum.—Below the transverse colon the arrangement is simple, as it includes only the main cavity; above the level of the transverse colon it is more complicated on account of the existence of the omental bursa. Below the transverse colon it may be considered in the two regions, viz. in the pelvis and in the abdomen proper.

(1) *In the pelvis.*—The peritoneum here follows closely the surfaces of the pelvic viscera and the inequalities of the pelvic walls, and presents important differences in the two sexes. (*a*) *In the male* (fig. 1091) it encircles the sigmoid colon, from which it is reflected to the posterior wall of the pelvis as a fold, the *sigmoid mesocolon*. It leaves the sides and, finally, the front of the rectum, and is continued over the upper parts of the seminal vesicles to the upper surface of the bladder; on either side of the rectum it forms a fossa, the *para-rectal fossa*, which varies in size with the distension of the rectum. In front of the rectum the peritoneum forms the rectovesical excavation, which is limited laterally by peritoneal folds extending from the sides of the bladder

to the rectum and sacrum. These folds are known, from their position, as the *rectovesical or sacrogenital folds.* The peritoneum of the anterior pelvic wall covers the superior surface of the bladder, and on either side of this viscus forms a depression, termed the *paravesical fossa,* which is limited laterally by the fold of peritoneum covering the ductus deferens. The size of this fossa is dependent on the state of distension of the bladder, and when the bladder is empty, a variable fold of peritoneum, the *plica vesicalis transversa,* divides the fossa into two portions. On the peritoneum between the paravesical and pararectal fossæ the only elevations are those produced by the ureters and the hypogastric vessels. (*b*) *In the female,* pararectal and paravesical fossæ similar to those in the male are present; the lateral limit of the paravesical fossa is the peritoneum investing the round ligament of the uterus. The rectovesical excavation is, however, divided by the uterus and vagina into a small anterior vesico-uterine and a large, deep, posterior recto-uterine

FIG. 1092.—The horizontal disposition of the peritoneum in the lower part of the abdomen.



excavation. The sacrogenital folds form the margins of the latter, and are continued on to the back of the uterus and the posterior fornix of the vagina as a transverse fold, the *torus uterinus.* The *broad ligaments* extend from the sides of the uterus to the lateral walls of the pelvis; they contain in their free margins the uterine tubes, and in their posterior layers the ovaries. Below, the broad ligaments are continuous with the peritoneum on the lateral walls of the pelvis. On the lateral pelvic wall behind the attachment of the broad ligament, in the angle between the elevations produced by the obliterated hypogastric artery and the ureter, is a slight fossa, the *ovarian fossa,* in which the ovary normally lies.

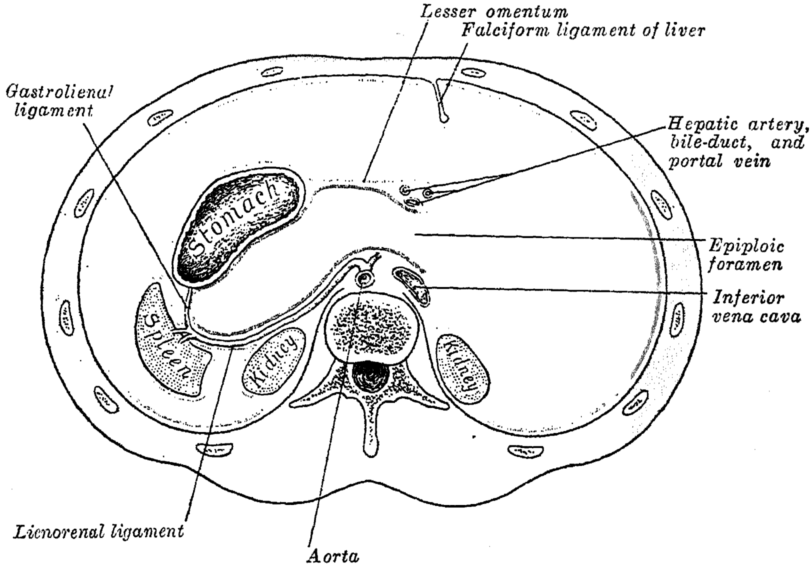
(2) *In the lower abdomen* (fig. 1092).—Starting from the linea alba, below the level of the transverse colon, and tracing the continuity of the peritoneum in a horizontal direction to the right, the membrane covers the inner surface of the abdominal wall almost as far as the lateral border of the Quadratus lumborum; it encloses the cæcum and vermiform process, and is reflected over the sides and front of the ascending colon; it may then be traced over the duodenum, Psoas major, and inferior vena cava towards the middle line, whence it passes along the mesenteric vessels to invest the small intestine, and back again to the large vessels in front of the vertebral column, forming the *mesentery,* between the layers of which are contained the jejunum, ileum, the

mesenteric blood-vessels, nerves, lacteals, and lymph-glands. It is then continued over the left Psoas major; it covers the sides and front of the descending colon, and, reaching the abdominal wall, is carried on it to the middle line.

(3) *In the upper abdomen* (fig. 1093).—Above the transverse colon the omental bursa is superadded to the main cavity, and the communication between them through the epiploic foramen can be demonstrated.

(*a*) *Main cavity.*—Commencing on the posterior abdominal wall at the inferior vena cava, the peritoneum may be followed to the right over the front of the right suprarenal gland and upper part of the right kidney to the antero-lateral abdominal wall. From the middle line of the anterior wall a backwardly directed fold encircles the obliterated umbilical vein and forms the falciform ligament of the liver. Continuing to the left, the peritoneum lines the antero-lateral abdominal wall and covers the lateral part of the front of the left kidney, and is reflected to the posterior border of the hilum of the spleen as the posterior

Fig. 1093.—The horizontal disposition of the peritoneum in the upper part of the abdomen.



layer of the *lienorenal ligament*. It can be traced over the surfaces of the spleen to the front of the hilum, and thence to the cardiac end of the greater curvature of the stomach as the anterior layer of the *gastrolienal ligament* (gastrosplenic omentum). It covers the anterosuperior surface of the stomach and commencement of the duodenum, and ascends from the lesser curvature of the stomach to the liver as the anterior layer of the lesser omentum.

(*b*) *Omental bursa.*—On the posterior abdominal wall the peritoneum of the general cavity is continuous with that of the omental bursa in front of the inferior vena cava. Starting from here, the bursa may be traced across the aorta and over the medial part of the front of the left kidney to the hilum of the spleen where the peritoneum forms the anterior layer of the lienorenal ligament. From the spleen it is reflected to the stomach as the posterior layer of the gastrolienal ligament. It covers the postero-inferior surface of the stomach and commencement of the duodenum, and extends upwards to the liver as the posterior layer of the lesser omentum; the right margin of this layer is continuous round the hepatic artery, bile-duct, and portal vein with the wall of the main cavity. The lienal vessels run between the two layers of the lienorenal ligament, and the short gastric and left gastro-epiploic vessels between the two layers of the gastrolienal ligament.

The *epiploic foramen* (foramen of Winslow) (figs. 1089, 1093) is the communication between the main cavity and the omental bursa. It is bounded

in front by the free border of the lesser omentum, with the bile-duct, hepatic artery, and portal vein between its two layers; *behind* by the peritoneum covering the inferior vena cava; *above* by the peritoneum on the caudate process of the liver, and *below* by the peritoneum covering the commencement of the duodenum and the hepatic artery, the latter passing forwards below the foramen before ascending between the two layers of the lesser omentum.

The boundaries and the extent of the omental bursa will now be evident. It is bounded *in front*, from above downwards, by the caudate lobe of the liver, the lesser omentum, the stomach, and the two anterior layers of the greater omentum. *Behind* it is limited, from below upwards, by the two posterior layers of the greater omentum, the transverse colon, and the ascending layer of the transverse mesocolon, the anterior surface of the pancreas, the left suprarenal gland, and the upper end of the left kidney. To the right of the œsophageal opening of the stomach it is bounded by that part of the Diaphragm which supports the caudate lobe of the liver and by the aorta and the inferior vena cava. Laterally, the bursa extends from the epiploic foramen to the spleen, where it is limited by the lienorenal and gastrolienal ligaments.

The omental bursa consists of a vestibule and three recesses, a superior, a middle and an inferior.

The *vestibule* is a narrow channel situated immediately to the left of the epiploic foramen, below the caudate process of the liver, above the head of the pancreas and superior part of the duodenum, and behind the hepatoduodenal ligament (p. 1141). The hepatic artery, portal vein, and bile-duct pass forwards below the vestibule and then ascend between the two layers of the hepato-duodenal ligament. The *superior* recess extends upwards from the vestibule behind the porta hepatis and the caudate lobe of the liver, and in front of the Diaphragm and aorta. The *middle* recess, a small but variable pouch, descends between the lesser omentum and the pancreas. The vestibule and the superior and middle recesses together constitute the *bursa omenti minoris*. The *inferior* recess, or *bursa omenti majoris*, lies behind the stomach and extends as a large *lienal recess* between the stomach and the spleen. In the fœtus the inferior recess reaches as low as the free margin of the greater omentum, but in the adult the vertical extent of the recess is much more limited owing to adhesions between the layers of the greater omentum.

The vestibule and the inferior recess are sometimes shut off from one another by a complete *septum bursarum*, but in most cases they communicate through a rounded opening, the *foramen bursæ omenti majoris*. This opening is limited posteriorly by the *gastropancreatic ligament*, a sickle-shaped fold of peritoneum which encloses the left gastric artery, and extends from the tuber omentale of the pancreas to the back of the fundus of the stomach.

Crymble * states that two gastropancreatic ligaments are frequently present, viz. a *vertical* fold attaching the posterior border of the lesser curvature of the stomach to the Diaphragm and pancreas, and a *horizontal* fold between the pyloric part of the stomach and the pancreas. He gives as the boundaries of the foramen bursæ omenti majoris, the lesser curvature of the stomach, the pancreas and the gastropancreatic ligaments. He found these ligaments absent in seven out of thirty-five subjects.

During a considerable part of fœtal life the transverse colon is suspended from the posterior abdominal wall by a mesentery of its own, the two posterior layers of the greater omentum passing at this stage in front of the colon (fig. 209). This condition occasionally persists throughout life, but as a rule adhesion occurs between the mesentery of the transverse colon and the posterior layer of the greater omentum, with the result that the colon appears to receive its peritoneal covering by the splitting of the two posterior layers of the latter fold. In the adult the omental bursa intervenes between the stomach and the structures on which that viscus lies, and performs therefore the functions of a serous bursa for the stomach.

Numerous peritoneal folds extend between the various organs or connect them to the parietes; they serve to hold the viscera in position, and, at the same time, enclose the vessels and nerves proceeding to them. They are grouped as ligaments, omenta, and mesenteries.

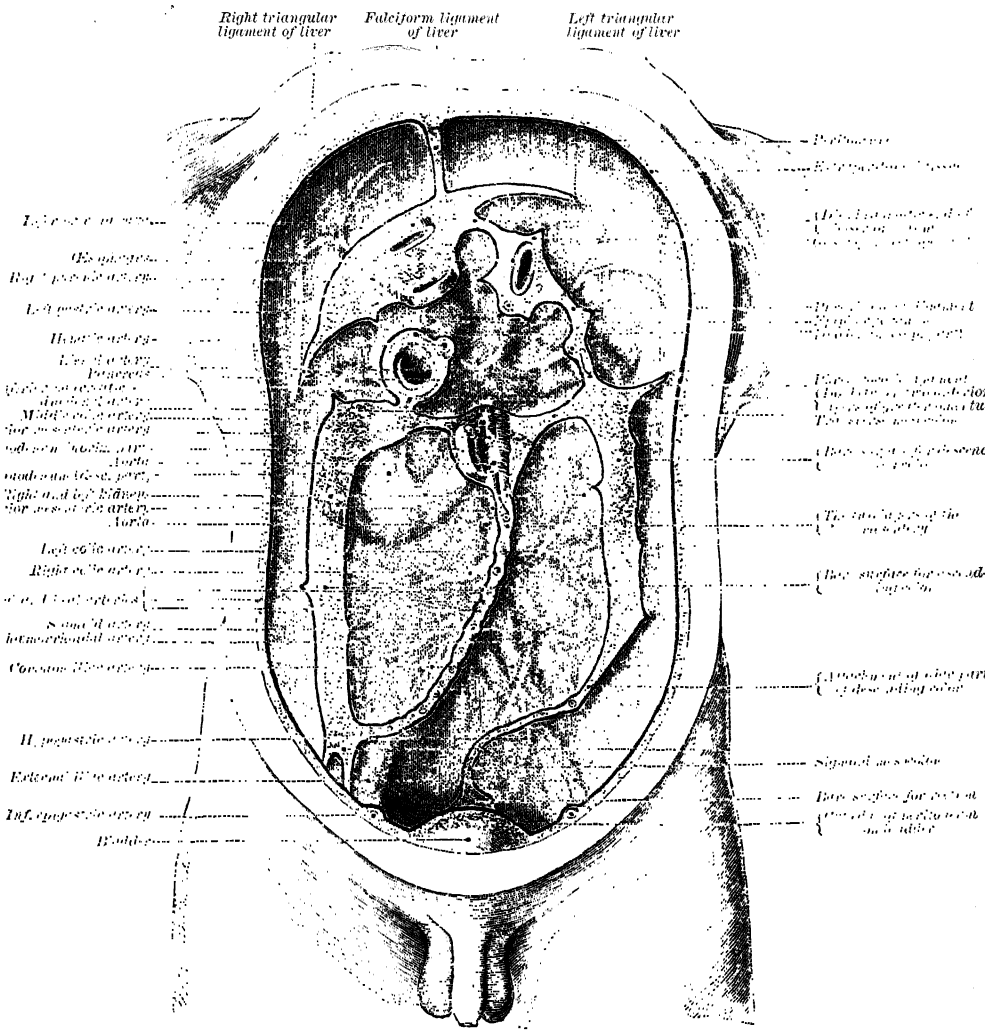
The ligaments will be described with their respective organs.

* *Journal of Anatomy and Physiology*, vol. xlvii.

There are two **omenta**, the lesser and the greater.

The *lesser omentum* is the fold of peritoneum which extends to the liver from the lesser curvature of the stomach and the commencement of the duodenum. It is continuous with the two layers which cover the antero-superior and postero-inferior surfaces of the stomach and the first part of the duodenum. When these two layers reach the lesser curvature of the

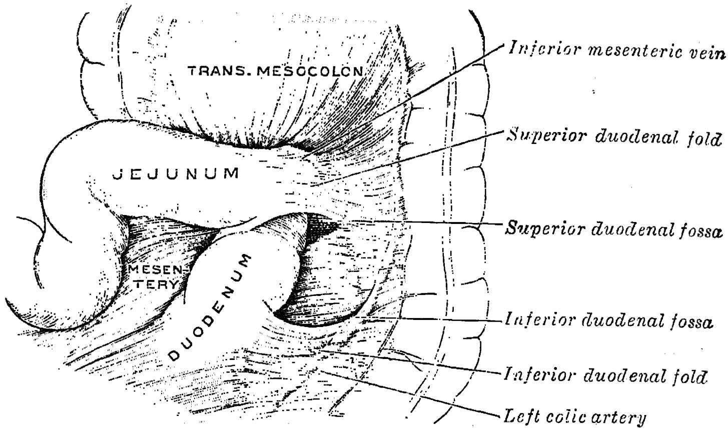
FIG. 1094.—A diagram devised by Delépine to show the lines along which the peritoneum leaves the wall of the abdomen to invest the viscera.



stomach and the upper border of the duodenum, they unite and ascend as a double fold to the porta hepatis ; to the left of the porta hepatis the fold is attached to the bottom of the fossa for the ductus venosus, along which it is carried to the Diaphragm, where the two layers separate to embrace the end of the œsophagus. At the right border of the omentum the two layers are continuous, and form a free margin which constitutes the anterior boundary of the epiploic foramen. The portion of the lesser omentum extending between the liver and stomach is named the *hepatogastric ligament*, while that between the liver and duodenum is the *hepatoduodenal ligament*. Between the two layers of the lesser omentum, close to the right free margin, are the hepatic artery, portal vein and bile-duct, a few lymph-glands and lymphatic vessels, and

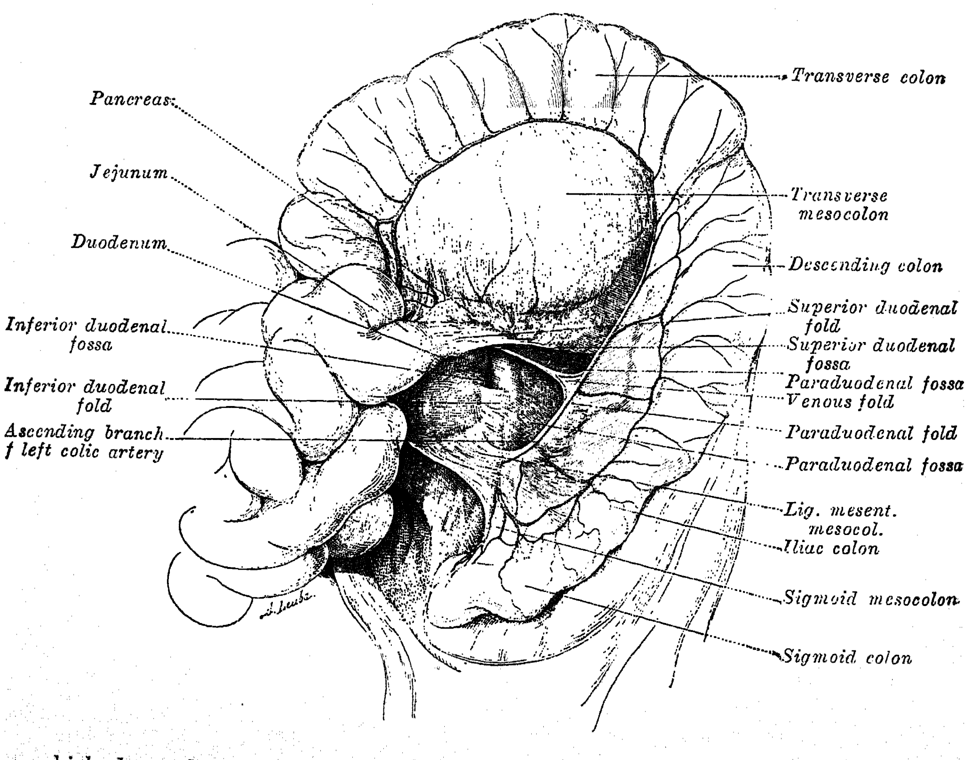
the hepatic plexus of nerves—all these structures being enclosed in a *fibrous capsule* (Glisson's capsule). The right and left gastric arteries run between the layers of the lesser omentum, where these are attached to the stomach.

FIG. 1095.—The superior and inferior duodenal fossæ. (After Jonnesco.) From Poirier and Charpy's Traité d'Anatomie humaine. (Masson et Cie.)



The *greater omentum* is the largest peritoneal fold. It consists of a double sheet, folded on itself so that it is made up of four layers. The two layers

FIG. 1096.—The paraduodenal fossa. (After Jonnesco.) From Poirier and Charpy's Traité d'Anatomie humaine. (Masson et Cie.)

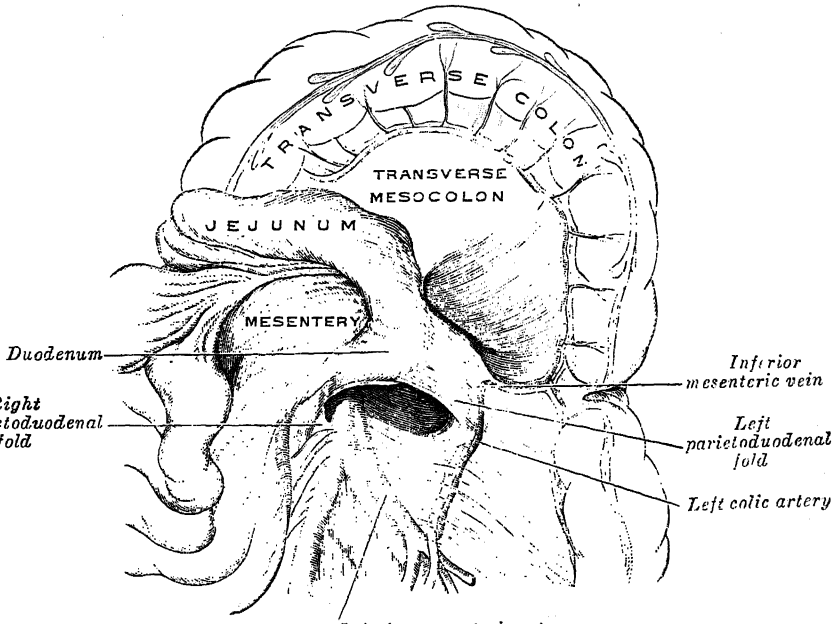


which descend from the stomach and commencement of the duodenum pass in front of the small intestines, sometimes as low down as the pelvis; they then

turn upon themselves, and ascend again as far as the transverse colon, where they separate and enclose that part of the intestine. These individual layers may be easily demonstrated in the young subject, but in the adult they are more or less inseparably blended. The left border of the greater omentum is continuous with the gastrolienal ligament; its right border extends as far as the commencement of the duodenum. The greater omentum is usually thin, presents a cribriform appearance, and always contains some adipose tissue, which in fat people accumulates in considerable quantity. Between its two anterior layers, a short distance from the greater curvature of the stomach, is the anastomosis between the right and left gastro-epiploic vessels.

The **mesenteries** are: the mesentery (mesentery proper), the mesenteriole of the vermiform process, the transverse mesocolon, and the sigmoid mesocolon. In addition to these an ascending and a descending mesocolon are sometimes present.

FIG. 1097.—The retroduodenal fossa. (After Jonnesco.) From Poirier and Charpy's Traité d'Anatomie humaine. (Masson et Cie.)



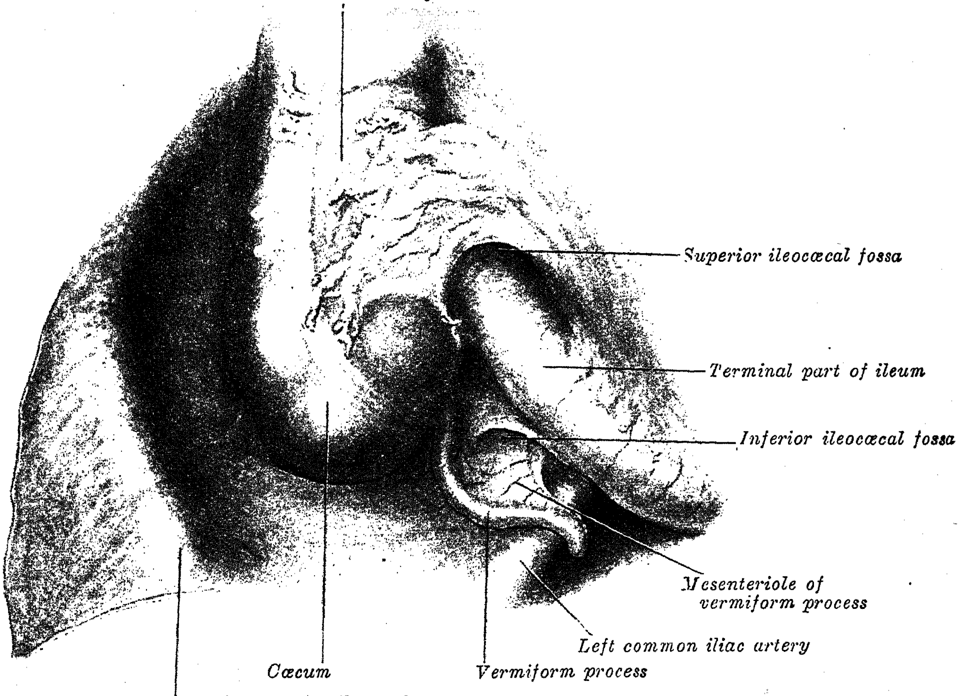
The *mesentery* is a broad, fan-shaped fold of peritoneum connecting the convolutions of the jejunum and ileum with the posterior wall of the abdomen. Its root—the border connected with the structures in front of the vertebral column—is about 15 cm. long, and is directed obliquely from the duodenojejunal flexure at the left side of the second lumbar vertebra to the right sacro-iliac articulation (fig. 1094). Its intestinal border is about 6 metres long; and here the two layers separate to enclose the intestine and form its peritoneal coat. The mesentery is short at the upper part of the jejunum, but lengthens rapidly to about 20 cm., and is thrown into numerous pleats or folds. It suspends the jejunum and ileum, and contains between its layers the jejunal and ileal branches of the superior mesenteric artery, with their accompanying veins and plexuses of nerves, the lymphatic (lacteal) vessels, the mesenteric lymph-glands, and a varying amount of fatty tissue.

The *mesenteriole of the vermiform process* (fig. 1098) is a triangular fold of peritoneum which clothes the vermiform process, and is attached to the back of the lower end of the mesentery, close to the ileocæcal junction. Between its layers are the blood-vessels, nerves and lymphatic vessels of the vermiform process, together with a lymph-gland.

The *transverse* mesocolon is a broad fold connecting the transverse colon to the posterior wall of the abdomen. It is continuous with the two posterior layers of the greater omentum, which, after separating to surround the transverse colon, join behind it, and are continued to the vertebral column, where they diverge in front of the anterior border of the pancreas. This fold contains between its layers the blood-vessels, nerves and lymphatics of the transverse colon.

The *sigmoid mesocolon* is a fold of peritoneum which attaches the sigmoid colon to the pelvic wall. Its line of attachment forms a V-shaped curve, the apex of the curve being placed near the point of division of the left common iliac artery. The curve begins on the medial side of the left Psoas major,

FIG. 1098.—The terminal part of the ileum, the cæcum and the vermiform process. Anterior aspect.



and runs upwards and backwards to the apex, from which it bends sharply downwards, and ends in the median plane at the level of the third sacral vertebra. The sigmoid and superior hæmorrhoidal vessels run between the two layers of the sigmoid mesocolon.

In most cases the peritoneum covers only the front and sides of the ascending and descending parts of the colon, but sometimes these are surrounded by peritoneum and attached to the posterior abdominal wall by an ascending and a descending mesocolon respectively (p. 1166*). A fold of peritoneum, the *phrenicocolic ligament*, is continued from the left colic flexure to the Diaphragm opposite the tenth and eleventh ribs ; it passes below, and serves to support, the spleen, and therefore has received the name of *sustentaculum lienis*.

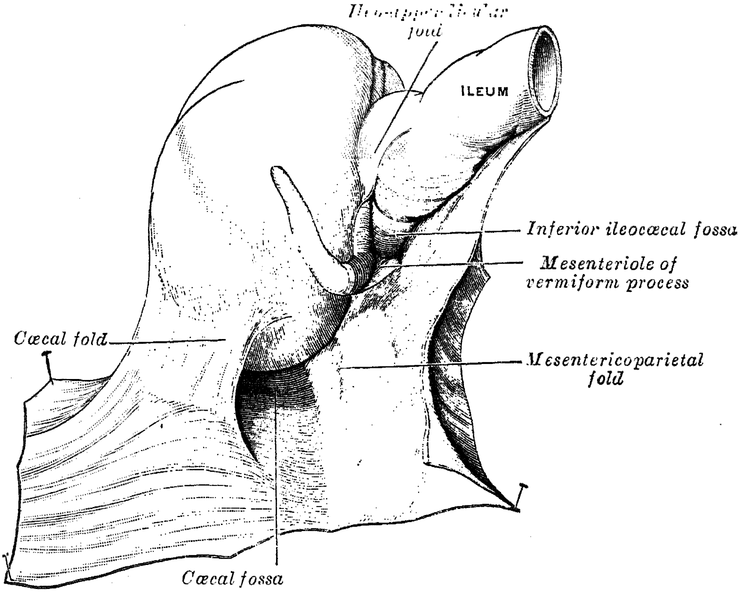
The *appendices epiploicæ* are small pouches of the peritoneum filled with fat and situated along the colon and upper part of the rectum. They are chiefly appended to the transverse and sigmoid parts of the colon.

Peritoneal recesses or fossæ.—In certain parts of the abdominal cavity there are peritoneal recesses or pouches, which are of surgical interest in connexion with the possibility of the occurrence of 'retroperitoneal'

herniæ. The largest of these is the omental bursa (p. 1139), but others of smaller size require mention, and may be divided into three groups, viz.: duodenal, cæcal, and intersigmoid.

1. *Duodenal fossæ* (figs. 1095 to 1097).—Five of these fossæ are usually described, viz. a superior and an inferior duodenal, a paraduodenal, a retroduodenal, and a duodenojejunal or mesocolic. The paraduodenal fossa may occur together with the superior and inferior duodenal fossæ, but the retroduodenal and duodenojejunal are not found in conjunction with the other varieties. (*a*) The *superior duodenal fossa* (fig. 1095) is present in about 50 per cent. of bodies. It lies on the left side of the upper segment of the ascending portion of the duodenum, behind a sickle-shaped fold of peritoneum, named

Fig. 1099.—The cæcal fossa. The ileum and cæcum are drawn backwards and upwards. (After Jonnesco.) From Poirier and Charpy's Traité d'Anatomie humaine. (Masson et Cie.)



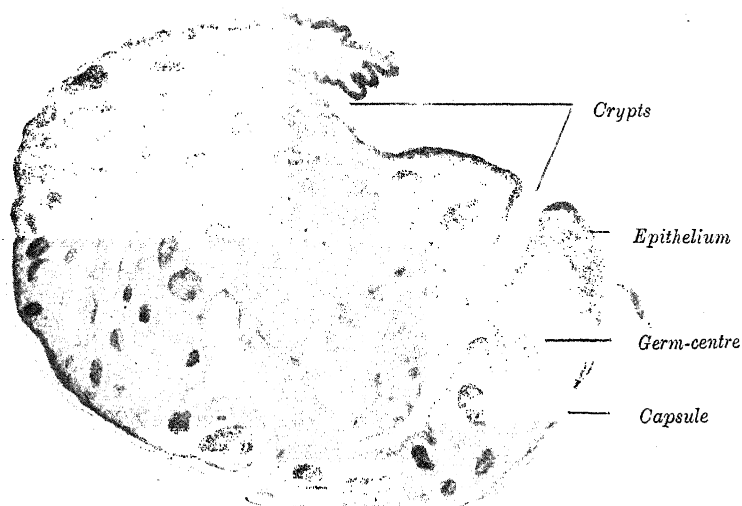
the superior duodenal fold; the upper part of the inferior mesenteric vein usually runs between the layers of this fold. The fossa is about 2 cm. deep, and its orifice, directed downwards, admits a finger-tip. (*b*) The *inferior duodenal fossa* (fig. 1095) is present in about 75 per cent. of bodies. It is placed on the left side of the lower segment of the ascending portion of the duodenum behind a nonvascular triangular fold of peritoneum, named the inferior duodenal fold. This fossa has an average depth of 3 cm., and its orifice, which admits the tips of one or two fingers, is directed upwards and faces that of the superior duodenal fossa. In some cases the fossa extends to the left in front of the ascending branch of the left colic artery, and the inferior mesenteric vein. (*c*) The *paraduodenal fossa* (fig. 1096) lies a short distance to the left of the ascending portion of the duodenum, and, though frequently present in the new-born child, is rarely found in the adult. It is placed behind a falciform fold (paraduodenal fold) of peritoneum, the free edge of which contains the ascending branch of the left colic artery, and frequently the inferior mesenteric vein, the fold forming a mesentery for these vessels. The free margin of the fold, and the wide orifice of the fossa, are directed towards the right. (*d*) The *retroduodenal fossa* (fig. 1097), the largest of the duodenal fossa, is only occasionally present. It lies behind the horizontal and ascending parts of the duodenum, and in front of the aorta. It extends upwards nearly as far as the duodenojejunal junction, and towards the left as far as, or beyond, the inferior mesenteric vein, which may run in its anterior wall. The orifice of the fossa looks downwards. (*e*) The *duodenojejunal or mesocolic fossa* lies on the left

The *lateral or deep surface* is adherent to a fibrous capsule which is continued into the plica triangularis. This surface is separated by some loose connective tissue from the Constrictor pharyngis superior ; this muscle intervenes between the tonsil and the external maxillary artery with its tonsillar and ascending palatine branches. Some muscular fibres are inserted into the lower and posterior parts of the capsule. The internal carotid artery lies about 2·5 cm. behind and lateral to the tonsil.

The palatine tonsils form part of a circular band of adenoid tissue which guards the opening into the digestive and respiratory tubes. The anterior part of the ring is formed by the submucous adenoid collections (lingual tonsil) on the pharyngeal part of the tongue ; the lateral portions consist of the palatine tonsils and the adenoid collections in the vicinity of the auditory tubes ; the ring is completed behind by the pharyngeal tonsil on the posterior wall of the pharynx. In the intervals between these main masses are smaller collections of adenoid tissue.

Structure (fig. 1080).—The crypts of the tonsil are lined by stratified squamous epithelium, which is continuous with that of the mucous membrane of the pharynx, and is invaded by numerous lymph-corpuscles ; probably some of the latter pass into the mouth and form the so-called salivary corpuscles. The tonsil consists of lymphoid tissue which is arranged in nodules or follicles. The lymphocytes are less closely packed in the centre of each nodule

FIG. 1080.—A section through a human tonsil. Stained with hæmatoxylin and eosin. ×8.



which is described as a *germ-centre*, because multiplication of the corpuscles goes on in this situation. Surrounding each follicle is a close plexus of lymphatics, from which the lymphatic vessels pass to the deep cervical lymph-glands in the neighbourhood of the greater cornu of the hyoid bone, behind and below the angle of the mandible (p. 756).

Vessels and Nerves.—The *arteries* supplying the tonsil are the dorsalis linguæ branches of the lingual artery, the ascending palatine and tonsillar branches of the external maxillary artery, the ascending pharyngeal branch of the external carotid artery, the descending palatine branch of the internal maxillary artery, and a twig from the small meningeal artery.

The *veins* end in the tonsillar plexus, on the lateral side of the tonsil.

The *nerves* are derived from the sphenopalatine ganglion, and from the glossopharyngeal nerve.

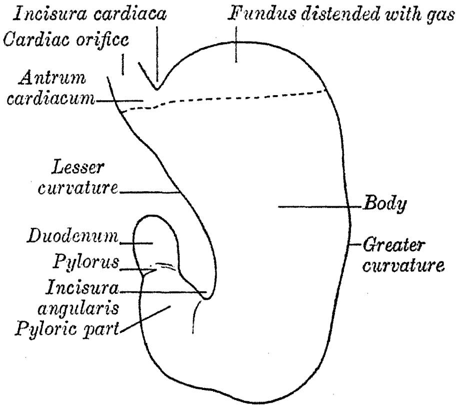
Applied Anatomy.—The palatine tonsils can be easily inspected by instructing the patient to throw the head back and open his mouth widely, the tongue at the same time being depressed by a spatula or tongue-depressor. The normal tonsil should not project beyond the plane of the glossopalatine arch. They are prone to become enlarged, especially in tuberculous children ; and when much increased in size they cause great trouble, owing to obstruction to respiration and deglutition. The tonsils may be the seat of acute inflammation, which may run on to suppuration, requiring evacuation of the pus. Pus

sharply to the left, the base of the cone being continuous with the cardiac orifice of the stomach. The right margin of the œsophagus is continuous with the lesser curvature of the stomach, while the left margin joins the greater curvature at an acute angle, termed the *incisura cardiaca*.

The opening by which the stomach communicates with the duodenum is named the *pyloric orifice*, and its position is usually indicated by a circular groove, the *duodenopyloric constriction* which indicates the position of the pyloric sphincter. The pyloric orifice lies to the right of the middle line at the level of the upper border of the first lumbar vertebra.

Curvatures.—The *lesser curvature*, extending between the cardiac and pyloric orifices, forms the right or posterior border of the stomach. It descends as a continuation of the right margin of the œsophagus in front of the fibres of the right crus of the Diaphragm, and then, turning to the right, it crosses the first lumbar vertebra and ends at the pylorus. Nearer its pyloric than its cardiac end is a notch, the *incisura angularis*, which varies somewhat in position with the state of distension of the viscus; it serves to separate the stomach into a right and a left portion. The lesser curvature gives attachment to the hepatogastric ligament, between the two layers of which are the right and left gastric arteries.

Fig. 1100.—An outline of the normal full stomach. (From a model by A. E. Barclay.)



The *greater curvature* is directed mainly forwards, and is four or five times as long as the lesser curvature. Starting from the cardiac orifice at the incisura cardiaca, it forms an arch backwards, upwards, and to the left; the highest point of the convexity is on a level with the sixth left costal cartilage. From this level it may be followed downwards and forwards, with a slight convexity to the left as low as the cartilage of the ninth rib; it then turns to the right, to end at the pylorus. Directly opposite the incisura angularis of the lesser curvature the greater curvature presents a bulging, which is the left extremity of the *pyloric part* of the stomach; this is limited on the right by a slight groove, the *sulcus intermedius*, which is from 2 to 3 cm. from the duodenopyloric constriction. At its commencement the greater curvature is covered by peritoneum continuous with that on the front of the stomach. The left part of the curvature gives attachment to the gastrolienal ligament, while to its anterior portion are attached the two layers of the greater omentum, separated from each other by the gastro-epiploic vessels.

Surfaces.—When the stomach is empty and its wall contracted, its surfaces are directed upwards and downwards respectively, but when it is distended they look forwards and backwards. They may therefore be described as anterosuperior and postero-inferior.

Anterosuperior surface.—The left half of this surface is in contact with the Diaphragm, which separates it from the base of the left lung, the pericardium, and the seventh, eighth, and ninth ribs and intercostal spaces of the left side. The right half is in relation with the left and quadrate lobes of the liver and with the anterior abdominal wall. When the stomach is empty, the transverse colon may lie on the front part of this surface. The whole surface is covered by peritoneum.

The *postero-inferior surface* is in relation with the Diaphragm, the gastric surface of the spleen, the left suprarenal gland, the upper part of the front of the left kidney, the anterior surface of the pancreas, the left colic flexure, and the upper layer of the transverse mesocolon. These structures form a shallow bed, the *stomach-bed*, on which the viscus rests. The transverse mesocolon separates the stomach from the duodenojejunal flexure and small intestine.

The postero-inferior surface is covered by peritoneum, except over a small area close to the cardiac orifice; this area is limited by the lines of attachment of the *gastrophrenic ligament,* and lies in apposition with the Diaphragm, and frequently with the upper portion of the left suprarenal gland.

FIG. 1101.—A diagram showing the shape and position of the empty stomach. Erect posture (After A. F. Hurst.)

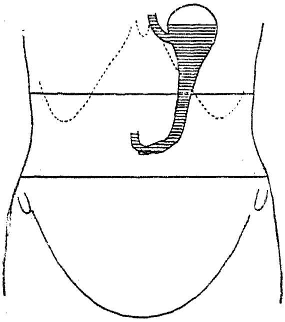


FIG. 1102.—A diagram showing the shape and position of the moderately filled stomach. Erect posture. (After A. F. Hurst.)

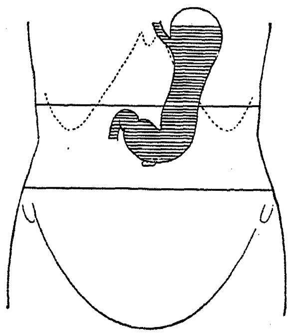
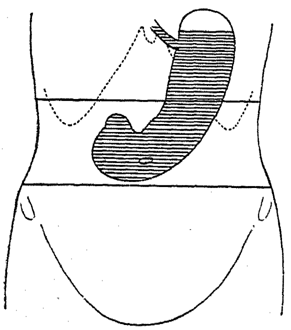


FIG. 1103.—A diagram showing the shape and position of the distended stomach. Erect posture. (After A. F. Hurst.)



Component parts of the stomach.—A plane passing through the incisura angularis on the lesser curvature and the left limit of the opposed bulging on the greater curvature divides the stomach into a large, left portion or *body* and a small, right or *pyloric portion.* The upper portion of the body is known as the *fundus* and is marked off from the remainder of the body by a plane passing horizontally through the cardiac orifice.

By means of x-rays the form and position of the stomach can be studied in the living subject after the administration of a meal containing bismuth. During the process of digestion, it is divided by a muscular constriction into a large dilated left portion, and a narrow contracted tubular right portion. The constriction is in the body of the stomach, and does not follow any of the anatomical landmarks; indeed, it shifts gradually towards the left as digestion progresses. The position of the stomach varies with the posture, with the amount of the stomach contents, and with the condition of the intestines on which it rests (figs. 1101 to 1103). In the erect posture the empty stomach is somewhat J-shaped; the part above the cardiac orifice is usually distended with gas; the pylorus descends to the level of the second lumbar vertebra, and the most dependent part of the stomach is at the level of the umbilicus. Variation in the amount of its contents affects mainly the body of the stomach, the pyloric portion remaining in a more or less contracted condition during the process of digestion. As the stomach fills it tends to expand forwards and downwards in the direction of least resistance, but when this is interfered with by a distended condition of the colon or intestines the fundus presses upwards on the liver and Diaphragm and gives rise to the feelings of oppression and palpitation complained of in such cases. His * and Cunningham † have shown by hardening the viscera *in situ* that the contracted stomach has a sickle shape, the fundus looking directly backwards. The surfaces are directed upwards and downwards, the upper surface having, however, a gradual downward slope to the right. The greater curvature is in front and at a slightly higher level than the lesser.

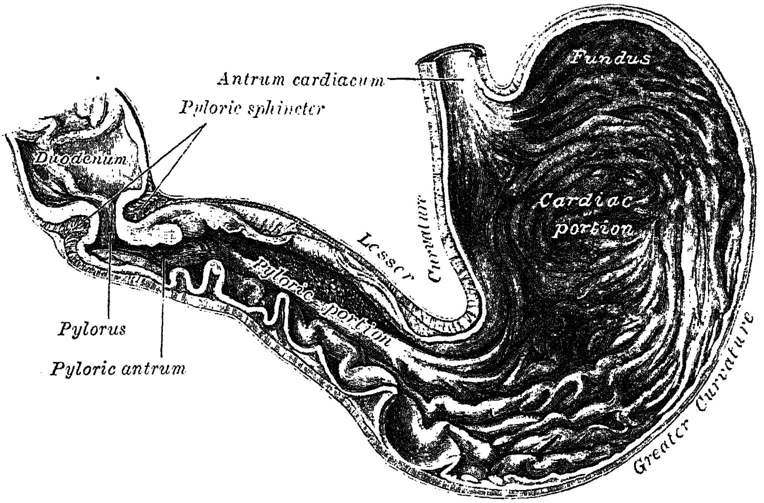
The position of the full stomach depends, as already indicated, on the state of the intestines: when the latter are empty the fundus expands vertically and also forwards, the pylorus is displaced towards the right, and the whole organ assumes an oblique position, so that its surfaces are directed more forwards and backwards. The lowest part of the stomach is at the pyloric vestibule which reaches to the region of the umbilicus. Where the intestines interfere with the downward expansion of the fundus the stomach retains the horizontal position which is characteristic of the contracted viscus.

Interior of the stomach.—When examined after death, the stomach is usually fixed at some temporary stage of the digestive process. A common form is that shown in fig. 1104. If the viscus be laid open by a section through the plane of its two curvatures, it is seen to consist of two segments: (*a*) a large globular portion on the left and (*b*) a narrow tubular part on the right. To the left of the antrum cardiacum is the incisura cardiaca:

* *Archiv für Anatomie und Physiologie, anat. Abth.*, 1903.
† *Transactions of the Royal Society of Edinburgh,* vol. xlv. part i.

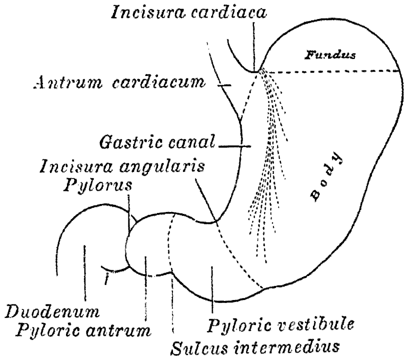
the projection of this notch into the cavity of the stomach increases as the organ distends, and has been supposed to act as a valve preventing regurgitation into the œsophagus. In the pyloric portion are seen: (*a*) the elevation corresponding to the incisura angularis, and (*b*) the circular thickening of the pyloric sphincter.

FIG. 1104.—The interior of the stomach.



F. T. Lewis * has modelled the gastric epithelium in the human embryo, and has shown that a canal (named by him the *gastric canal*) extends along the lesser curvature from the antrum cardiacum to the incisura angularis (fig. 1105), the distinctness of the canal being strikingly shown when the model is viewed from the inside. Jefferson † has brought forward radiographic evidence to show that such a canal exists in the adult. He found that in eighteen out of twenty-two cases examined whilst in the act of swallowing a mixture of oxychloride of bismuth and milk the fluid was confined to the lesser curvature. He is of the opinion that the oblique muscular coat of the stomach is so arranged that by its contraction it will cause a temporary cutting off of a canal along the lesser curvature.

FIG. 1105.—A diagram showing the subdivisions of the human stomach. (F. T. Lewis.)



The *pyloric sphincter* is a muscular ring composed of a thickened portion of the circular layer of the muscular coat; this ring is covered by a reduplication of the mucous membrane. Some of the deeper longitudinal fibres turn in and interlace with the fibres of the sphincter.

Structure.—The wall of the stomach consists of four coats: serous, muscular, areolar, and mucous, together with vessels and nerves.

The *serous coat* is derived from the peritoneum, and covers the entire surface of the organ, excepting (*a*) along the greater and lesser curvatures at the lines of attachment of the greater and lesser omenta, where the two layers of peritoneum leave a small space, triangular in section, in which the vessels and nerves pass; and (*b*) a small area on the postero-inferior surface of the stomach, close to the cardiac orifice, where the stomach is in contact with the under surface of the Diaphragm.

* *American Journal of Anatomy*, vol. xiii.
† *Journal of Anatomy and Physiology*, vol. xlix.

The *muscular coat* (figs. 1106, 1107) is situated immediately beneath the serous covering, with which it is closely connected. It consists of three layers of unstriped muscular fibres: longitudinal, circular, and oblique.

FIG. 1106.—The longitudinal and circular muscular fibres of the stomach. Anterosuperior aspect. (Spalteholz.)

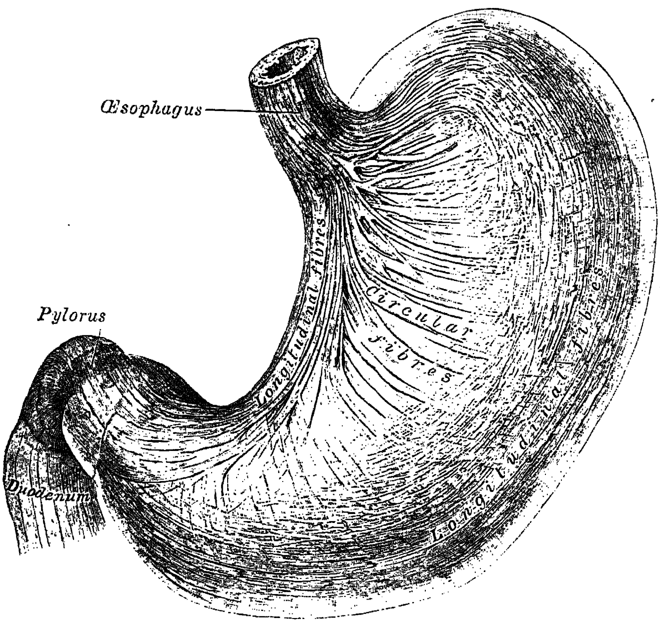
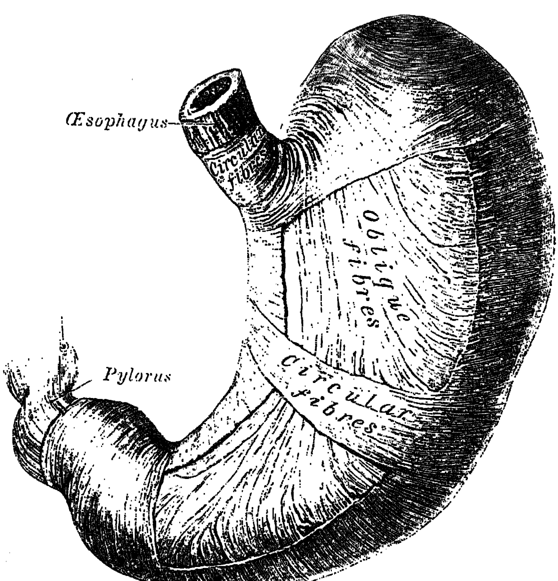


FIG. 1107.—The oblique muscular fibres of the stomach. Anterosuperior aspect. (Spalteholz.)



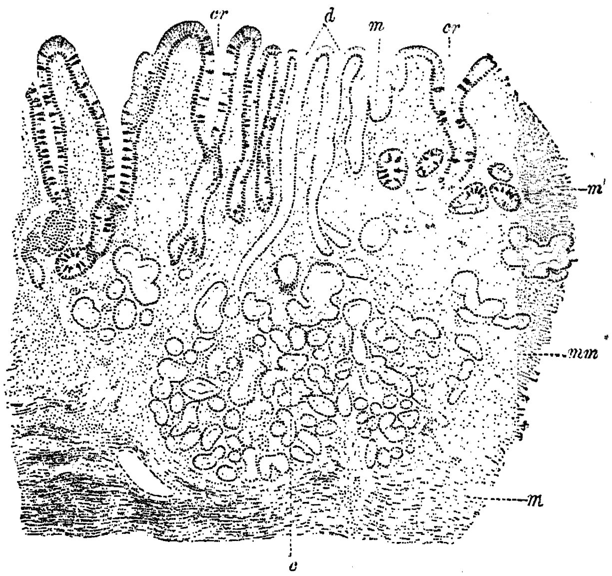
The *longitudinal fibres* are the most superficial, and are arranged in two sets. The first set consists of fibres continuous with the longitudinal fibres of the œsophagus; they radiate from the cardiac orifice and end proximal to the pyloric portion. The second set

commences on the body of the stomach and passes to the right, its fibres becoming more thickly arranged as they approach the pylorus. Some of the more superficial fibres of this set pass on to the duodenum, but the deeper fibres dip inwards and interlace with the fibres of the pyloric sphincter.

The *circular fibres* form a uniform layer over the whole extent of the stomach beneath the longitudinal fibres. At the pylorus they are most abundant, and are there aggregated into a ring, which forms the *pyloric sphincter*. The circular fibres of the stomach are continuous with the circular fibres of the œsophagus, but are sharply marked off from the circular fibres of the duodenum by a connective tissue septum.

The *oblique fibres*, internal to the circular layer, are limited chiefly to the body of the stomach. They sweep downwards from the incisura cardiaca and run more or less parallel with the lesser curvature. On the right they present a free and well-defined margin (fig. 1107); on the left they blend with the circular fibres.

FIG. 1108.—A section through the mucous membrane of a human stomach, near the cardiac orifice. ×45. (v. Ebner, after J. Schaffer.)



c. Cardiac glands. *d.* Their ducts. *cr.* Gland similar to the intestinal glands, with goblet-cells. *mm.* Mucous membrane. *m.* Muscularis mucosæ. *m'.* Muscular tissue within the mucous membrane.

The *areolar or submucous coat* consists of loose, areolar tissue, connecting the mucous and muscular layers.

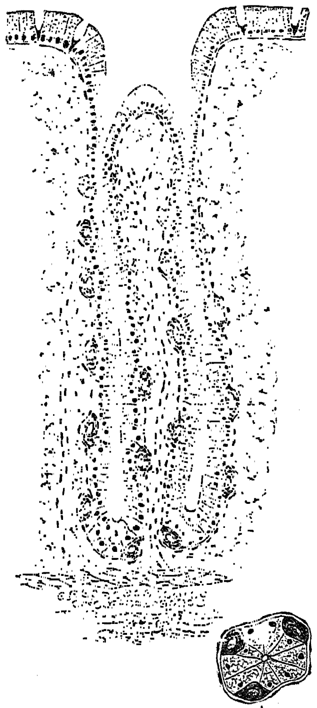
The *mucous membrane* is thick and its surface is smooth, soft, and velvety. In the fresh state it is of a pinkish tinge at the pyloric end, and of a red or reddish-brown colour over the rest of its surface. In infancy it is of a brighter hue, the vascular redness being more marked. It is thin at the cardiac extremity, but thicker towards the pylorus. During the contracted state of the organ it is thrown into numerous folds or rugæ, which for the most part have a longitudinal direction, and are best marked towards the pyloric end of the stomach, and along the greater curvature (fig. 1104). These folds are obliterated when the organ is distended.

Structure of the mucous membrane.—When examined with a lens, the inner surface of the mucous membrane presents a peculiar honeycomb appearance from being covered with small shallow depressions or alveoli, of a polygonal or hexagonal form, which vary from 0·12 mm. to 0·25 mm. in diameter. These are the ducts of the gastric glands, and at the bottom of each may be seen one or more minute orifices, the openings of the gland-tubes. The surface of the mucous membrane is covered by a single layer of columnar epithelium with occasional goblet-cells. This epithelium commences very abruptly at the cardiac orifice, where there is a sudden transition from the stratified epithelium of the œsophagus. The epithelial lining of the gland-ducts is of the same character and is continuous with the general epithelial lining of the stomach.

The gastric glands are of three kinds: (*a*) *cardiac*, (*b*) *fundus or oxyntic*, and (*c*) *pyloric*. The *cardiac glands* (fig. 1108), few in number, occur close to the cardiac orifice. They are of two kinds: (1) simple tubular glands resembling those of the pyloric end of

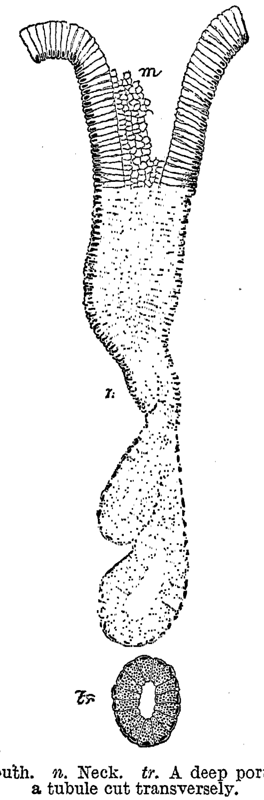
the stomach, but with short ducts; (2) compound racemose glands resembling the duodenal glands. The *fundus glands* (fig. 1109) are found in the body and fundus of the stomach; they are simple tubes, two or more of which open into a single duct. The duct is short, sometimes not amounting to more than one-sixth of the whole length of the gland. The epithelium of the fundus glands consists of (1) short columnar, granular cells, known as the *chief* or *central cells*, and (2) larger, oval cells, termed *parietal* or *oxyntic cells*. The latter lie between the chief cells and the basement-membrane, and stain deeply with eosin; they do not form a continuous layer, but occur at intervals and so give the tube a beaded appearance. They are connected with the lumen of the gland by fine channels which run in the substance of the cells. The *pyloric glands* (fig. 1110) are found in the

FIG. 1109.—A fundus gland.



A. A transverse section through the gland.

FIG. 1110.—A pyloric gland, from a section through a dog's stomach. (Ebstein.) (From Quain's Elements of Anatomy, Vol. II. Pt. I.)



m. Mouth. *n.* Neck. *tr.* A deep portion of a tubule cut transversely.

pyloric portion of the stomach. Each consists of two or three short convoluted tubes opening into a funnel-shaped duct. The tubes are lined by cubical cells which are finely granular. Parietal or oxyntic cells are present in some of the pyloric glands. The ducts occupy about two-thirds of the depth of the mucous membrane.

Between the glands the mucous membrane consists of a connective tissue framework, with lymphoid tissue. In places, this latter tissue, especially in early life, is collected into little masses, which resemble the solitary lymphatic nodules of the intestine, and are termed the *lenticular glands* of the stomach. They are not, however, so distinctly circumscribed as the solitary nodules. The mucous membrane is bounded on its deep surface by a thin stratum of involuntary muscular fibres (muscularis mucosæ), which in some parts consists only of a single longitudinal layer; in others of two layers, an inner circular and an outer longitudinal.

Vessels and Nerves.—The *arteries* supplying the stomach are: the left gastric branch of the cœliac artery, the right gastric and right gastro-epiploic branches of the hepatic artery, and the left gastro-epiploic and short gastric branches of the lienal artery. They supply the muscular coat, ramify in the submucous coat, and are finally distributed to the mucous membrane. The arrangement of the vessels in the mucous membrane is somewhat peculiar. The arteries break up at the deep ends of the gastric glands into a

plexus of fine capillaries which run upwards between the glands, anastomosing with each other, and ending in a plexus of larger capillaries, which surround the mouths of the glands, and also form hexagonal meshes around the gland-ducts. From these the *veins* arise, and pursue a straight course downwards, between the glands, to the submucous tissue; they end either in the lienal and superior mesenteric veins, or directly in the portal vein. The *lymphatic vessels* are numerous; they consist of a superficial and a deep set, and pass to the lymph-glands found along the two curvatures of the organ (p. 769). The *nerves* are the terminal branches of the right and left vagi, the former being distributed upon the back, and the latter upon the front part of the stomach. A great number of branches from the cœliac plexus of the sympathetic are also distributed to it. Nerve-plexuses are found in the submucous coat and between the layers of the muscular coat, as in the intestine. From these plexuses fibrils are distributed to the muscular tissue and the mucous membrane.

Applied Anatomy.—Operations on the stomach are frequently performed. By 'gastrotomy' is meant an incision into the stomach for the removal of a foreign body, the opening being immediately afterwards closed—in contradistinction to 'gastrostomy,' the making of a more or less permanent fistulous opening for purposes of feeding, when the patient cannot obtain sufficient nourishment owing to some form of œsophageal obstruction.

In cases of gastric ulcer perforation of the stomach not infrequently takes place. By opening the abdomen and closing the perforation, the vast majority of cases are cured, provided the operation is done not longer than twelve or fifteen hours after the perforation has taken place. The opening, which is generally situated on the anterior surface of the stomach near the pylorus, is best closed by bringing the peritoneal surfaces on either side into apposition by means of Lembert's sutures.

Excision of the pylorus has occasionally been performed, but the results of this operation are by no means favourable, and, in cases of cancer of the pylorus, before operative proceedings are undertaken, the tumour has become so fixed and has so far implicated surrounding parts that removal of the pylorus is impossible and *gastro-enterostomy* has to be substituted. The object of this operation is to make a fistulous communication between the stomach, on the cardiac side of the disease, and the small intestine, as high up as is possible. It gives great relief in any form of obstruction to the pylorus, especially when associated with dilatation of the stomach. In this operation either the anterior or the posterior surface of the stomach may be anastomosed to the jejunum, the latter for preference, in which case an opening has first to be made through the transverse mesocolon in order to reach the lesser sac. This opening must particularly avoid the middle colic vessels. In cases of cancer of the stomach involving other parts than the pylorus, the question of removing the whole or greater part of the stomach has to be considered.

Hypertrophy and spasm of the circumferential muscular coat of the pylorus coming on during the first few weeks or months of life, and somewhat erroneously described as *congenital hypertrophic stenosis of the pylorus*, is a serious disorder of infancy. It is characterised by abdominal pains and obstinate vomiting coming on after food has been given. Gastric peristalsis can be observed by inspection of the child's epigastrium after it has been fed and before vomiting has occurred. Progressive wasting from want of nourishment, and death from exhaustion, tend to ensue. Gastro-enterostomy gives favourable results in a small proportion of cases.

The stomach is seldom ruptured from external violence, on account of its protected position. If it occurs, it is when the organ is distended with food. The stomach is sometimes injured in gunshot wounds. There is intense shock and severe pain, localised at first at the seat of the injury, but soon radiating over the whole abdomen. The treatment consists in opening the peritoneal cavity, clearing away all the extruded contents of the stomach, and repairing the rent.

The Small Intestine (Intestinum Tenue)

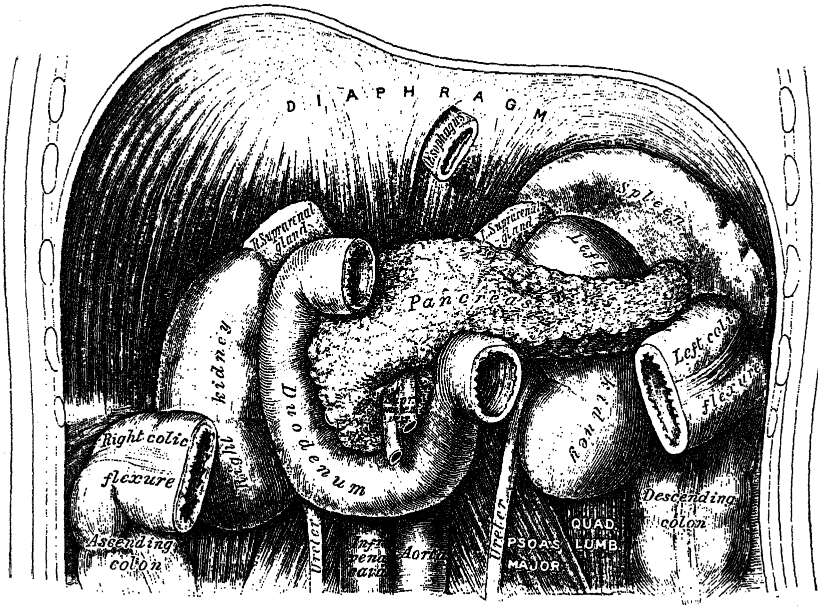
The **small intestine** is a convoluted tube, extending from the pylorus to the colic valve, where it joins the large intestine. It is about 6·5 metres long, and gradually diminishes in diameter from its commencement to its termination. It is contained in the central and lower parts of the abdominal cavity and is surrounded above and at the sides by the large intestine; it is in relation, in front, with the greater omentum and abdominal parietes; a portion of it extends below the superior aperture of the pelvis and lies in front of the rectum. The small intestine consists of (1) a short, curved portion which is devoid of a mesentery and is named the duodenum, and (2) a long, greatly coiled part which is attached to the posterior abdominal wall by the mesentery (p. 1143), and is named the intestinum tenue mesenteriale; the proximal two-fifths of

the latter constitute the jejunum (intestinum jejunum), the distal three-fifths the ileum (intestinum ileum).

The **duodenum** (fig. 1111) is so named because its length is about equal to the breadth of twelve fingers (25 cm.). It is the shortest, widest, and most fixed part of the small intestine; it has no mesentery, and is only partially covered by peritoneum. Its course presents a remarkable curve, somewhat of the shape of an imperfect circle.

It begins at the pylorus, passes backwards, upwards and to the right, beneath the quadrate lobe of the liver to the neck of the gall-bladder, varying slightly in direction according to the degree of distension of the stomach; it then makes a sharp curve (superior duodenal flexure) and descends along the right margin of the head of the pancreas, for a variable distance, generally to the level of the upper border of the body of the fourth lumbar vertebra. It now makes a second bend (inferior duodenal flexure), and passes almost horizontally from right to left across the vertebral column, having a slight

FIG. 1111.—The duodenum and pancreas. Exposed from the front.



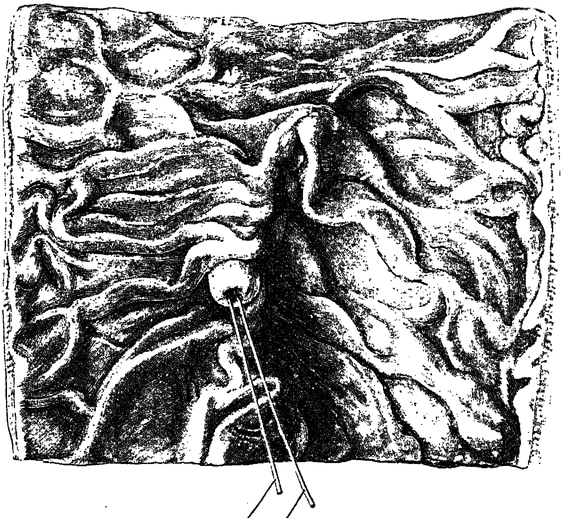
inclination upwards; it then ascends in front of the abdominal aorta for about 2·5 cm., and ends opposite the second lumbar vertebra in the jejunum. At its union with the jejunum it turns abruptly forwards, forming the *duodeno-jejunal flexure*. For descriptive purposes it is divided into superior, descending, horizontal, and ascending portions.

Relations.—The *superior portion* is about 5 cm. long, and is the most movable of the four portions; it begins at the pylorus, and ends at the neck of the gall-bladder. It is covered by peritoneum with the exception of a small part of its posterior surface near the neck of the gall-bladder and the inferior vena cava; the hepatoduodenal ligament is attached to the upper border, and the greater omentum to the lower border of the proximal half. It is in relation above and in front with the quadrate lobe of the liver and the gall-bladder; behind with the gastroduodenal artery, the bile-duct, and the portal vein; and below and behind with the head and neck of the pancreas. It is in such close relation with the gall-bladder that it is usually found to be stained by bile after death, especially on its anterior surface.

The *descending portion*, from 8 cm. to 10 cm. long, descends from the neck of the gall-bladder along the right side of the vertebral column as low as the upper border of the body of the fourth lumbar vertebra. It is crossed by the

transverse colon, the posterior surface of which is connected to the duodenum by a small quantity of connective tissue. The parts above and below the transverse colon are covered in front by peritoneum. It is in relation, in front, from above downwards, with the duodenal impression on the right lobe of the liver, the transverse colon, and the small intestine; behind, it has a variable relation to the front of the right kidney in the neighbourhood of its hilum, and is connected to it by loose areolar tissue; the renal vessels, the right edge of the inferior vena cava, and the Psoas major, are also behind it. At its medial side is the head of the pancreas, and the bile-duct; at its lateral side is the right colic flexure. The bile-duct and the pancreatic duct together perforate the medial side of this portion of the duodenum obliquely, and open by a common orifice on the summit of a papilla (*papilla duodeni*) (figs. 1112, 1137), from 8 cm. to 10 cm. distal to the pylorus; the accessory pancreatic duct, when present, pierces it about 2 cm. proximal to and slightly in front of the papilla duodeni.

FIG. 1112.—The interior of the descending portion of the duodenum, showing the papilla duodeni.



The *horizontal portion*, about 10 cm. long, begins at the right side of the upper border of the fourth lumbar vertebra and passes from right to left, with a slight inclination upwards, in front of the inferior vena cava, and ends in the ascending portion in front of the abdominal aorta. Its anterior surface is covered by peritoneum, except near the middle line, where it is crossed by the superior mesenteric vessels. Its posterior surface is uncovered by peritoneum, except towards its left extremity, where the posterior layer of the mesentery sometimes covers it to a variable extent. This surface rests upon the right ureter, the right Psoas major, the right testicular vessels, the inferior vena cava. The upper surface is in relation with the head of the pancreas; the lower, with the coils of the jejunum.

The *ascending portion*, about 2·5 cm. long, ascends on the aorta, as far as the level of the upper border of the second lumbar vertebra, where it turns abruptly forwards (*duodenojejunal flexure*) and is continuous with the jejunum. It lies in front of the left Psoas major, the left renal and testicular vessels, and is covered in front, and partly at the sides, by peritoneum continuous with the left portion of the mesentery.

The superior part of the duodenum, as stated above, is somewhat movable, but the rest is practically fixed, and is bound down to neighbouring viscera and the posterior abdominal wall. In addition to this, the ascending part of

the duodenum and the duodenojejunal flexure are fixed by the *Musculus suspensorius duodeni* (muscle of Treitz) which arises from the right crus of the Diaphragm, close to the right margin of the œsophagus. It passes downwards and slightly forwards in close relation with the cœliac artery (sometimes dividing to enclose this vessel) and is attached to the posterior surface of the upper part of the duodenojejunal flexure, many fibres being continued into the mesentery.* This muscle consists of three parts, viz. an upper of striped muscular fibres, an intermediate elastic tendon, and a lower of unstriped muscular fibres.

Vessels and Nerves.—The *arteries* supplying the duodenum are the right gastric and superior pancreaticoduodenal branches of the hepatic, and the inferior pancreaticoduodenal branch of the superior mesenteric. The *veins* end in the lienal and superior mesenteric veins. The *nerves* are derived from the cœliac plexus.

The **mesenteric part** of the small intestine (intestinum tenue mesenteriale), about 6 metres long, extends from the duodenojejunal flexure to the colic valve, where it ends in the cæcum of the large intestine; it is arranged in a series of coils or loops which are attached to the posterior abdominal wall by the mesentery. It is divided into jejunum and ileum, the former name being given to the upper two-fifths and the latter to the lower three-fifths. There is no morphological line of distinction between these two parts, and the division is arbitrary; but at the same time the character of the intestine gradually undergoes a change from the beginning of the jejunum to the end of the ileum, so that portions of the bowel taken from these two situations present characteristic differences.

The **jejunum** (intestinum jejunum) has a diameter of about 4 cm., and is thicker, redder and more vascular than the ileum. The circular folds or valvulæ conniventes (p. 1158) of its mucous membrane are large and thickly set, and its villi surpass those of the ileum in size. The aggregated lymphatic-nodules (p. 1160) are almost absent in the upper part of the jejunum; in the lower part they are less frequently found than in the ileum, and are smaller and tend to assume a circular form. By grasping the jejunum between the finger and thumb the circular folds can be felt through the wall of the gut; as these folds are absent from the lower part of the ileum, it is possible in this way to distinguish the upper from the lower part of the small intestine.

The **ileum** (intestinum ileum) has a diameter of 3·5 cm., and its coats are thinner than those of the jejunum. A few circular folds are present in the upper part of the ileum, but they are small and disappear almost entirely towards its lower end; the aggregated lymphatic-nodules (Peyer's glands) are, however, larger and more numerous than in the jejunum. The jejunum for the most part occupies the umbilical and left iliac regions, while the ileum is situated chiefly in the umbilical, hypogastric, right iliac, and pelvic regions. The terminal part of the ileum usually lies in the pelvis, from which it ascends over the right Psoas major and right iliac vessels; it ends in the right iliac fossa by opening into the medial side of the cæcum.

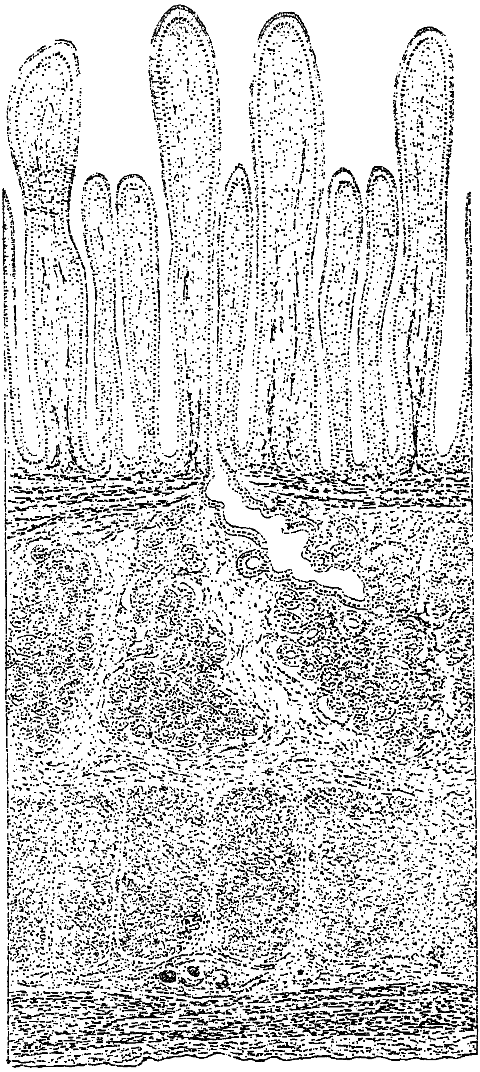
The jejunum and ileum are attached to the posterior abdominal wall by an extensive fold of peritoneum, the *mesentery*, which allows of very free motion, so that each coil can accommodate itself to changes in form and position. The mesentery is fan-shaped; its vertebral border or root, about 15 cm. long, is attached to the posterior abdominal wall along a line running from the left side of the body of the second lumbar vertebra to the right sacro-iliac articulation, and crossing successively the horizontal part of the duodenum, the aorta, the inferior vena cava, the right ureter, and right Psoas major (fig. 1094). Its average breadth from the vertebral to the intestinal border is about 20 cm., but is greater in the middle than at its upper and lower ends; according to Lockwood the breadth of the mesentery tends to increase as age advances. Between the two layers of the mesentery are contained the jejunum, ileum, the jejunal and ileal branches of the superior mesenteric blood-vessels, nerves, lacteals, and lymph-glands, together with a variable amount of fat.

Meckel's diverticulum.—This is a pouch which projects from the lower part of the ileum in about 2 per cent. of subjects. Its average position is about 1 metre above the

* A. Low, *Journal of Anatomy and Physiology*, vol. xlii.

colic valve, and its average length about 5 cm. Its calibre is generally similar to that of the ileum, and its blind extremity may be free or may be connected with the abdominal wall or with some other portion of the intestine by a fibrous band. It represents the remains of the proximal part of the vitelline duct, the duct of communication between the yolk-sac and the primitive digestive tube in early fœtal life (p. 56).

FIG. 1113.—A section through the duodenum of a cat. ×60. (From Sharpey Schafer's Essentials of Histology.)



Structure.—The wall of the small intestine (fig. 1113) is composed of four coats: serous, muscular, areolar, and mucous.

The *serous coat* is formed of peritoneum. The superior portion of the duodenum is almost completely surrounded by this membrane near its pyloric end, but is only covered in front at the other extremity; the descending portion is covered by it in front, except where it is in contact with the transverse colon; and the inferior portion lies behind the peritoneum, which is separated from it in and near the middle line by the superior mesenteric vessels. The rest of the small intestine is surrounded by the peritoneum, excepting along its attached or mesenteric border; here a space is left for the vessels and nerves to enter the wall of the gut.

The *muscular coat* is thicker in the upper than in the lower part of the small intestine; it consists of an external longitudinal, and an internal circular layer of non-striped

muscular fibres. The *longitudinal layer* is thin; the *circular layer* is thick, and composed of fibres of considerable length.

The *areolar or submucous coat* unites the mucous and muscular layers. It consists of loose, areolar tissue containing blood-vessels, lymphatic vessels, and nerves.

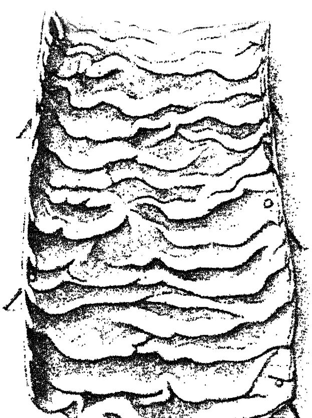
The *mucous membrane* is thick and highly vascular in the upper part of the small intestine, but thinner and less vascular in the lower part. It consists of the following structures: next the areolar or submucous coat is the *muscularis mucosæ*, consisting of an outer longitudinal and inner circular layer of unstriped muscular fibres; internal to the muscularis mucosæ is a quantity of retiform tissue, enclosing in its meshes lymph-corpuscles, and in which the blood-vessels and nerves ramify; lastly, a basement-membrane, supporting a single layer of tall columnar cells. The cells are granular in appearance, and each possesses a clear oval nucleus. At their superficial or unattached ends is a distinct layer of highly refracting material, marked by vertical striæ (the *striated border*). Goblet-cells occur at intervals in the epithelial layer.

Contained within or belonging to the mucous membrane are the following structures:

Circular folds.	Duodenal glands.
Villi.	Solitary lymphatic nodules.
Intestinal glands.	Aggregated lymphatic nodules.

The **circular folds** or **valvulæ conniventes** (fig. 1114) are large transverse folds of mucous membrane which project into the lumen of the bowel. They are composed of reduplications of the mucous membrane, the two layers of the fold being bound together by submucous tissue; unlike the folds in the stomach, they are permanent, and are not obliterated when the intestine is distended. The majority extend transversely round the intestine for about one-half or two-thirds of its circumference, but some form complete circles, some bifurcate and join adjacent folds, and others have a spiral direction; the latter usually extend a little more than once round the bowel, but occasionally two or three times. The larger folds are about 8 mm. in depth at their broadest part; but the greater number are of smaller size. The larger and smaller folds alternate with each other. Circular folds are not found at the commencement of the duodenum, but begin to appear about 2·5 or 5 cm. beyond the pylorus. Distal to the point where the bile- and pancreatic ducts enter the duodenum, they are very large and closely approximated. In the upper one-half of the jejunum they are large and numerous, but from this point, down to the middle of the ileum, they diminish considerably in size. In the lower part of the ileum they are almost entirely absent; hence the comparative thinness of this portion of the intestine, as compared with the duodenum and jejunum. The circular folds retard the passage of the food along the intestine, and afford an increased surface for absorption.

FIG. 1114.—The interior of a portion of the upper part of the jejunum, showing the circular folds.



The **intestinal villi** are highly vascular processes, just visible to the naked eye; they project from the mucous membrane of the whole of the small intestine, and give to its surface a velvety appearance. They are large and numerous in the duodenum and jejunum, but are smaller and fewer in the ileum.

Structure of the villi (figs. 1115, 1116).—The essential parts of a villus are: the lacteal vessel, the blood-vessels, the epithelium, the basement-membrane and the muscular tissue of the mucosa, all being supported and held together by retiform tissue.

The *lacteals* are in some cases double, and in some animals multiple, but usually there is a single vessel. Situated in the axis of the villus, each commences by a dilated blind extremity near to, but not quite at, the summit of the villus. The wall is composed of a single layer of endothelial cells.

The *muscular fibres* are derived from the muscularis mucosæ, and are arranged in bundles around the lacteal vessel, extending from the base to the summit of the villus, and giving off, laterally, individual muscle cells, which are enclosed by the reticulum, and by it are attached to the basement-membrane and to the lacteal.

The *blood-vessels* (fig. 1117) form a plexus under the basement-membrane, and are enclosed in the reticular tissue.

These structures are surrounded by the *basement-membrane*, which is made up of a stratum of endothelial cells and upon this is placed a layer of *columnar epithelium*, the characteristics of which have been described above. The *retiform tissue* forms a network (fig. 1116) in the meshes of which a number of leucocytes are found.

FIG. 1115.—A vertical section through a villus of the small intestine of a dog. × 80.

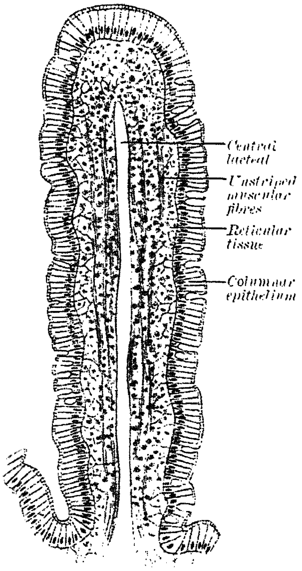
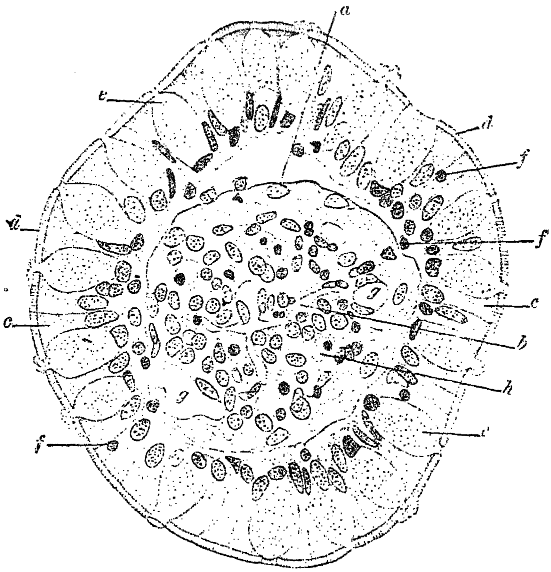
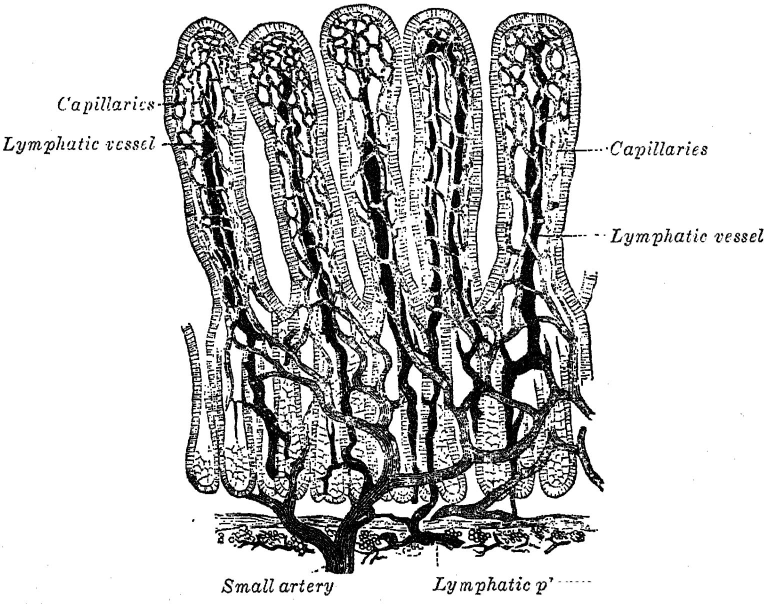


FIG. 1116.—A transverse section through a villus of the human intestine. × 350. (v. Ebner.)



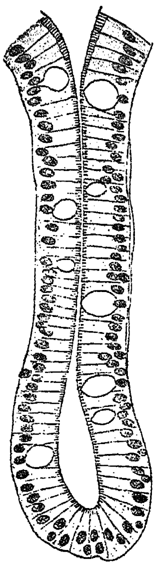
a. Basement-membrane, here somewhat shrunken away from the epithelium. *b*. Lacteal. *c*. Columnar epithelium; *d*. its striated border. *e*. Goblet-cells. *f*. Leucocytes in epithelium. *f'*. Leucocyte below epithelium. *g*. Blood-vessels. *h*. Muscle-cells cut across.

FIG. 1117.—The villi of the small intestine, showing the blood-vessels and the lymphatic vessels. (Cadiat.)



The **intestinal glands** (crypts of Lieberkühn) (fig. 1118) are found in considerable numbers over every part of the mucous membrane of the small intestine. They are simple tubular glands, arranged perpendicularly to the surface, upon which they open by small circular apertures. Their orifices may be seen with the aid of a lens as minute dots scattered between the villi. Their walls are thin, consisting of a basement-membrane lined by columnar epithelium, and covered on their exterior by capillary vessels.

FIG. 1118.—An intestinal gland from the human intestine. (Flemming.) (From Quain's Elements of Anatomy.)

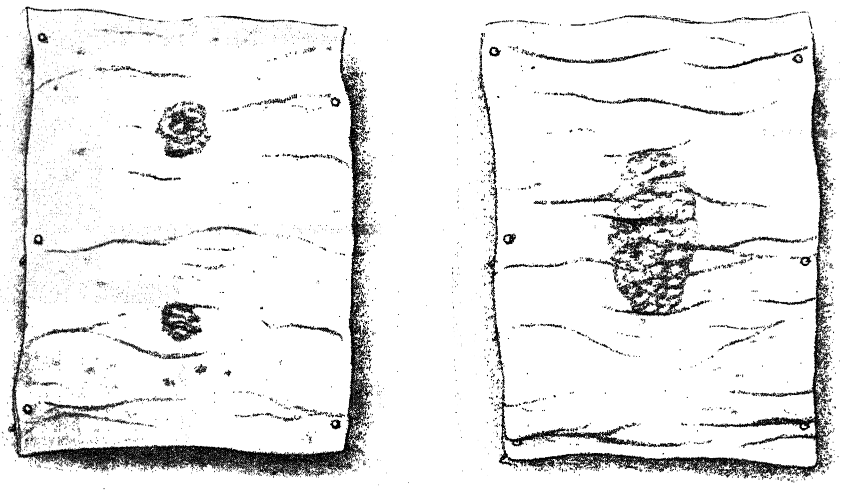


The **duodenal glands** (Brunner's glands) are limited to the duodenum (fig. 1113), and are found in the submucous areolar tissue. They are largest and most numerous near the pylorus, forming an almost complete layer in the superior portion, and upper half of the descending portion, of the duodenum; beyond this they gradually diminish in number and disappear at the junction of the duodenum and jejunum. They are small compound acinotubular glands, each consisting of a number of alveoli lined by short columnar epithelium and opening by a duct on the inner surface of the intestine.

The **solitary lymphatic nodules** are found scattered throughout the mucous membrane of the small intestine, but are most numerous in the lower part of the ileum. Their free surfaces are covered with rudimentary villi, except at the summits, and each nodule is surrounded by the openings of the intestinal glands. Each consists of a dense interlacing retiform tissue closely packed with lymph-corpuscles, and permeated by an abundant capillary network. The interspaces of the retiform tissue are continuous with larger lymph-spaces which surround the nodule, through which they communicate with the lacteal system. They are situated partly in the submucous tissue, partly in the mucous coat, where they form slight projections of its epithelial layer.

The **aggregated lymphatic nodules** (Peyer's glands) (figs. 1119, 1120) form circular or oblong patches, from twenty to thirty in number, and varying in length from 2 cm. to 10 cm. They are best marked in the young subject, become indistinct in middle age, and sometimes disappear altogether in advanced life. They are largest and most numerous in the ileum. In the lower part of the jejunum they are small, circular, and few in number. They are occasionally seen in the duodenum. They are placed lengthwise in the intestine, and are situated in the portion of the tube most distant from the attachment of the mesentery. Each patch is formed of a group of solitary lymphatic nodules

FIG. 1119.—Aggregated lymphatic nodules. A, from the upper part, and B, from the lower part, of the ileum.



A B

When dissecting the soft palate from its posterior or pharyngeal, to its anterior or oral, surface, the muscles are exposed in the following order: (1) the posterior fasciculus of the Pharyngopalatinus, covered posteriorly by a continuation of the nasal mucous membrane; (2) the Musculus uvulæ; (3) the Levator veli palatini; (4) the anterior fasciculus of the Pharyngopalatinus; (5) the aponeurosis of the Tensor veli palatini; and (6) the Glossopalatinus, covered anteriorly by a continuation of the oral mucous membrane.

The Mechanism of Deglutition

During the first stage of deglutition, the bolus of food is driven through the isthmus faucium by the pressure of the anterior part of the tongue against the hard palate, the posterior part of the tongue being, at the same time, retracted, and the larynx raised with the pharynx. During the second stage the entrance to the larynx is closed by the meeting of the aryepiglottic folds, and by the approximation of the arytænoid cartilages to the tubercle or cushion of the epiglottis—a movement produced by the contraction of the Thyreoarytænoidei, the Arytænoidei obliqui, and the Aryepiglottici.

After leaving the tongue the bolus passes on to the posterior or laryngeal surface of the epiglottis, and glides along this for a certain distance; then the Glossopalatini, the constrictors of the fauces, contract behind it; the palatine velum is slightly raised by the Levator veli palatini, and made tense by the Tensor veli palatini; and the Pharyngopalatini, by their contraction, pull the pharynx upwards over the bolus, and come nearly together, the uvula filling up the slight interval between them. By these means the food is prevented from passing into the nasal part of the pharynx; at the same time, the Pharyngopalatini form an inclined plane, directed obliquely downwards and backwards, along the under surface of which the bolus descends into the lower part of the pharynx. The later stages of deglutition are carried on by the muscles of the pharynx (p. 1125).

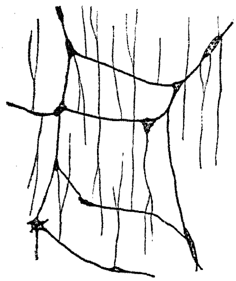
The Pharynx (fig. 1082)

The **pharynx** is the part of the digestive tube which is placed behind the nasal cavities, the mouth, and the larynx. It is a musculomembranous tube, from 12 to 14 cm. long, which extends from the under surface of the skull to the sixth cervical vertebra and the lower border of the cricoid cartilage. Its width at the level of the pharyngeal recesses or fossæ of Rosenmüller is 3·5 cm.; at the junction of the pharynx with the œsophagus it is reduced to about 1·5 cm. The pharynx is limited, *above*, by the body of the sphenoidal bone and the basilar part of the occipital bone; *below*, it is continuous with the œsophagus; *behind*, it is connected by loose areolar tissue with the cervical portion of the vertebral column and the prevertebral fascia covering the Longus colli and Longus capitis muscles; *in front*, it opens into the nasal cavities, the mouth and the larynx, and therefore its anterior wall is incomplete. It is attached from above downwards, on either side, to the medial pterygoid lamina, pterygomandibular raphe, mandible, tongue, hyoid bone, and thyreoid and cricoid cartilages; *laterally*, it communicates with the tympanic cavities through the auditory (Eustachian) tubes, and is in relation with the styloid processes and their muscles, the common and external carotid arteries, and some of the branches of the latter artery. The pharynx consists of three parts: nasal, oral, and laryngeal (fig. 1082).

The **nasal part of the pharynx** (nasopharynx) lies behind the nose and above the level of the soft palate. With the exception of the soft palate its walls are immovable, and consequently its cavity is never obliterated; in this respect it differs from the oral and laryngeal parts. In front (fig. 1083) it communicates with the nasal cavities through the choanæ; these measure about 25 mm. vertically, and 12·5 mm. transversely, and are separated by the posterior edge of the nasal septum. Behind the lower edge of the soft palate it opens into the oral part of the pharynx; in the act of swallowing this opening is closed by the elevation of the soft palate. On each lateral wall behind the middle nasal concha is the *pharyngeal ostium of the auditory tube*, somewhat triangular in shape, and bounded behind by a firm prominence, the *torus*

the free border, where they also anastomose with other branches running round the opposite surface of the gut. From these vessels numerous branches are given off, which pierce the muscular coat, supplying it and forming an intricate plexus in the submucous tissue. From this plexus minute vessels pass to the glands and villi of the mucous membrane. The *veins* have a course and arrangement similar to the arteries. The *lymphatic vessels* of the small intestine (lacteals) are arranged in two sets, those of the mucous membrane and those of the muscular coat. The lymphatic vessels of the villi commence in these structures in the manner described on p. 1158. They form an intricate plexus in the mucous and submucous tissue, being joined by the lymphatic vessels from the lymph-spaces at the bases of the solitary nodules, and from this pass to larger vessels at the mesenteric border of the gut. The lymphatic vessels of the muscular coat are situated to a great extent between the two layers of muscular fibres, where they form a close plexus; throughout their course they communicate freely with those from the mucous membrane, and open in the same manner as these into the origins of the lacteal vessels at the attached border of the gut.

FIG. 1123.—The plexus of the submucosa of the rabbit. × 50.



The *nerves* of the small intestine are derived from the vagus and splanchnic nerves through the cœliac ganglia and the plexuses around the superior mesenteric artery. They run to the *myenteric plexus* (*Auerbach's plexus*) (fig. 1122) of nerves and ganglia, situated between the circular and longitudinal layers; from this plexus filaments are distributed to the muscular coats of the intestine. From the myenteric plexus a secondary plexus, the *plexus of the submucosa* (*Meissner's plexus*) (fig. 1123), is derived, and is formed by branches which have perforated the circular muscular layer. This plexus also contains ganglia from which the nerve-fibres pass to the muscularis mucosæ and to the mucous membrane. The nerve-bundles of the submucous plexus are finer than those of the myenteric plexus.

Keith states that 'Auerbach's plexus is not composed simply of ganglionic cells and nerve-fibres; it contains numerous other cells to which Kölliker called attention, and which may be described as Kölliker's cells. These cells have small bodies which send out numerous branched processes, and differ from pure sheath-cells in staining reaction and structure. It is through these cells that Auerbach's tissue is linked up with the musculature of the bowel. The nerve-fibres which former authors have described as distributed to the muscular and other coats of the bowel are probably sensory in nature. Sections of the developing bowel show that the outer and inner muscular coats are developed from a germinal layer situated between them. Auerbach's plexus represents the residue of the germinal or developmental intermediate layer. Probably the ganglionic cells may be of central origin, but the cells of Kölliker are apparently undifferentiated muscle-cells.' He states that in point of development Auerbach's plexus is similar in origin to that of the atrioventricular bundle of His, and is of opinion that they are homologous.*

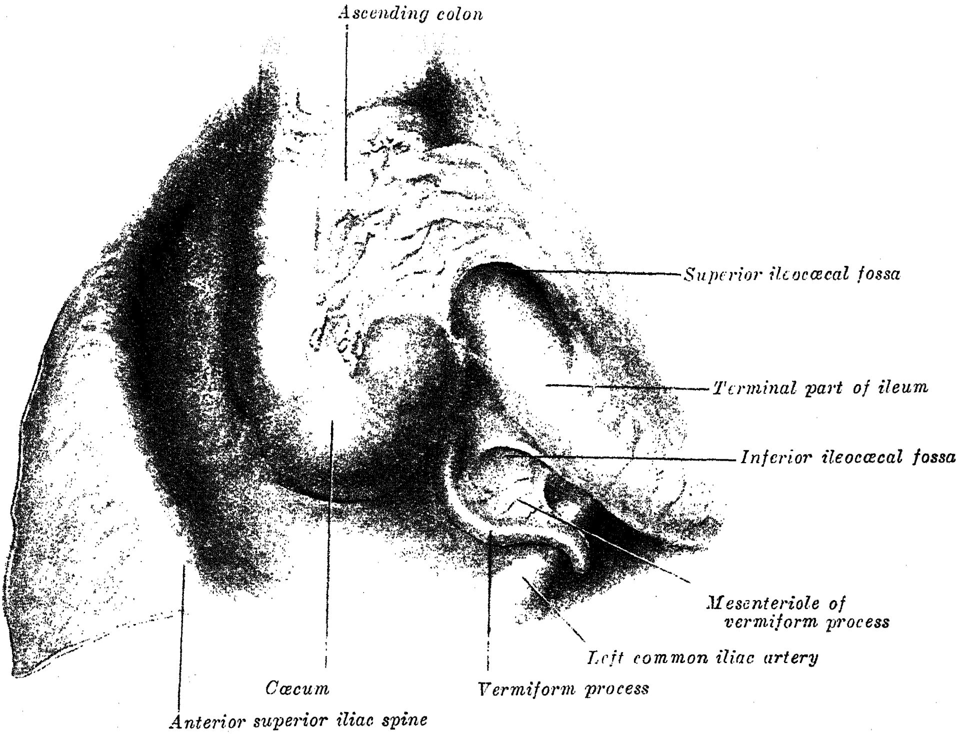
THE LARGE INTESTINE (INTESTINUM CRASSUM)

The **large intestine** extends from the end of the ileum to the anus, and is about 1·5 metres long. Its calibre is largest at its commencement at the cæcum, and gradually diminishes as far as the rectum, where there is a dilatation of considerable size just above the anal canal. It differs from the small intestine in its greater calibre, its more fixed position, its sacculated form, and in possessing certain appendages to its external coat, the *appendices epiploicæ*. Further, its longitudinal muscular fibres do not form a continuous layer around the gut, but are arranged in three longitudinal bands or *tæniæ*. In its course the large intestine describes an arch which surrounds the convolutions of the small intestine. It commences in the right iliac region, in a dilated part, the *cæcum*. It ascends through the right lumbar and hypochondriac regions to the under surface of the liver; here it bends (the *right colic flexure*) to the left, and passes across the abdomen to the left hypochondriac region; it then bends again (the *left colic flexure*), and descends through the left lumbar and iliac regions to the pelvis, where it forms a loop called the *sigmoid flexure*; from this it is continued along the lower part of the posterior wall of the pelvis to the anus. It is divided into the cæcum, the colon, the rectum, and the anal canal.

* *Proceedings of the Anatomical Society of Great Britain and Ireland*, January 1915.

The **cæcum** (fig. 1124), the commencement of the large intestine, is the large pouch situated below the level of the colic valve. Its closed end is directed downwards, and its open end upwards, communicating directly with the colon, of which the cæcum appears to be the beginning or head, and hence the name *caput cæcum coli* was formerly applied to it. Its average length is about 6 cm. and its breadth about 7·5 cm. It is situated in the right iliac fossa, above the lateral half of the inguinal ligament: it rests on the Iliacus and Psoas major, and is usually in contact with the anterior abdominal wall, but the greater omentum, and, if the cæcum be empty, some coils of small intestine, may lie in front of it. As a rule, it is entirely enveloped by peritoneum, but in about

Fig. 1124.—The terminal part of the ileum, the cæcum and the vermiform process. Anterior aspect.



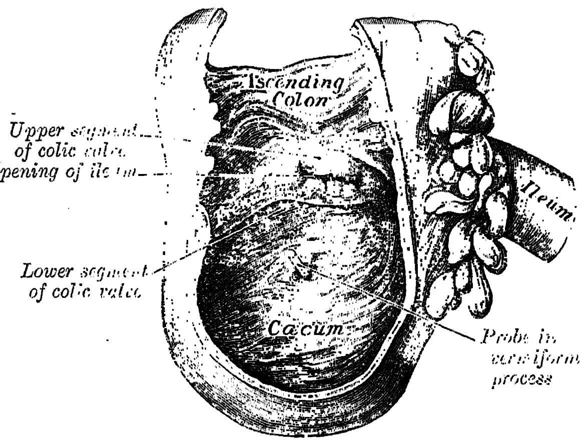
5 per cent. of cases (Berry) the peritoneal covering is incomplete, the upper part of the posterior surface being uncovered, and connected to the iliac fascia by connective tissue. The cæcum enjoys a considerable amount of movement, so that it may become herniated down the right inguinal canal, and has occasionally been found in an inguinal hernia on the left side.

The cæcum varies in shape, but, according to Treves, it may be classified under one of four types. In early fœtal life it is short, conical, and broad at the base, with its apex turned upwards and medialwards towards the ileocolic junction. It then resembles the cæcum of the mangabey monkey. As the fœtus grows, the cæcum increases in length more than in breadth, so that it forms a longer tube than in the primitive form and without the broad base, but with the same inclination of the apex towards the ileocolic junction. This form is seen in the spider monkey. As development goes on, the lower part of the tube ceases to grow and the upper part becomes greatly increased, so that at birth there is a narrow tube, the vermiform process, hanging from a conical projection, the cæcum. This is the infantile form, and as it persists throughout life in about 2 per cent. of subjects, it is regarded by Treves as the *first* of his four types of human cæca. The cæcum is conical and the appendix rises from its apex. The three tæniæ coli (p. 1170) start from the appendix and are equidistant from each other. In the *second* type, the conical cæcum has become

quadrate by the growing out of a saccule on either side of the anterior tænia. These saccules are of equal size, and the appendix arises from between them, instead of from the apex of a cone. This type is found in about 3 per cent. of subjects. The *third* type is the normal type of man. Here the two saccules, which in the second type were uniform, have grown at unequal rates: the right with greater rapidity than the left. In consequence of this an apparently new apex has been formed by the growing downwards of the right saccule, and the original apex, with the appendix attached, is pushed over to the left towards the ileocolic junction. The three tæniæ still start from the base of the vermiform process, but they are now no longer equidistant from each other, because the right saccule has grown between the anterior and posterolateral tæniæ, pushing them over to the left. This type occurs in about 90 per cent. of subjects. The *fourth* type is merely an exaggerated condition of the third; the right saccule is still larger, and at the same time the left saccule has become atrophied, so that the original apex of the cæcum, with the vermiform process, is close to the ileocolic junction, and the anterior tænia courses medialwards to the same situation. This type is present in about 4 per cent. of subjects.

The colic valve (fig. 1125).—The lower end of the ileum opens into the medial and posterior part of the large intestine, at the point of junction of the cæcum with the colon. The opening is guarded by a valve, consisting of two segments or lips, which project into the lumen of the large intestine. If the intestine has been inflated and dried, the lips are of a semilunar shape. The upper lip, nearly horizontal in direction, is attached by its convex border to the line of junction of the ileum with the colon; the lower lip, the longer and more concave, is attached to the line of junction of the ileum with the cæcum. At the ends of the aperture the two segments of the valve coalesce, and are continued as narrow membranous ridges around the canal for a short distance, forming the *frenula* of the valve. The left or anterior end of the aperture is rounded; the right or posterior is narrow and pointed. In the fresh condition, or in specimens which have been hardened *in situ*, the circular muscular coat of the ileum is thickened to form a sphincter-like valve, while the lips of the valve project as thick folds into the lumen of the cæcum, and the opening between them may present the appearance of a slit or may be somewhat oval in shape.

FIG. 1125.—The interior of the cæcum and the lower end of the ascending colon, showing the colic valve.



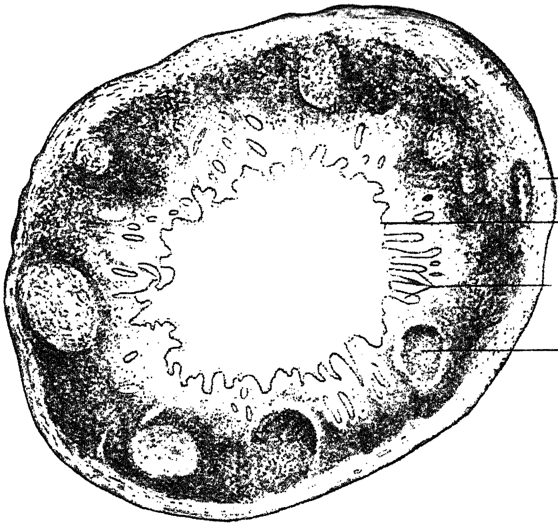
Each lip of the valve is formed by a reduplication of the mucous membrane and of the circular muscular fibres of the intestine, the longitudinal fibres and peritoneum being continued uninterruptedly from the small to the large intestine.

The surfaces of the valve directed towards the ileum are covered with villi and present the characteristic structure of the mucous membrane of the small intestine; while those turned towards the large intestine are destitute of villi and marked with the orifices of the numerous tubular glands peculiar to the mucous membrane of the large intestine. It was formerly maintained that this valve prevented reflux from the cæcum into the ileum, but in all probability it acts as a sphincter round the end of the ileum and prevents the contents of the ileum from passing too quickly into the cæcum; the valve is kept in a condition of tonic contraction by impulses which reach it through the splanchnic nerves.

The vermiform process or appendix (fig. 1124) is a long, narrow, worm-shaped tube, which starts from what was originally the apex of the cæcum,

and may pass in one of several directions: upwards behind the cæcum; to the left behind the ileum and mesentery; or downwards into the lesser pelvis. It varies from 2 cm. to 20 cm. in length, the average being about 9 cm. It is connected by a fold of peritoneum (mesenteriole) to the lower part of the mesentery of the ileum. This fold, in the majority of cases, is more or less triangular in shape, and as a rule extends along the entire length of the tube. Between the two layers of the mesenteriole, and close to its free margin, lies the appendicular artery. The canal of the vermiform process is small, and communicates with the cæcum by an orifice which is placed below and behind the ileocolic opening. The orifice is sometimes guarded by a semilunar valve formed by a fold of mucous membrane.

FIG. 1126.—A transverse section through the human vermiform process. ×20.



Structure.—The coats of the vermiform process are the same as those of the intestine: serous, muscular, submucous, and mucous. The *serous* coat forms a complete investment for the tube, except along the narrow line of attachment of its mesenteriole. The *longitudinal muscular fibres* do not form three bands as in the greater part of the large intestine, but invest the whole organ, except at one or two points where both the longitudinal and circular layers are deficient, so that the peritoneal and submucous coats are contiguous over small areas. The *circular muscular fibres* form a thicker layer than the longitudinal fibres, and are separated from them by a small amount of connective tissue. The *submucous* coat is well developed, and contains a large number of masses of lymphoid tissue which cause the mucous membrane to bulge into the lumen and so render the latter of small size and irregular shape. The *mucous membrane* is lined by columnar epithelium and resembles that of the rest of the large intestine, but the intestinal glands are fewer in number (fig. 1126).

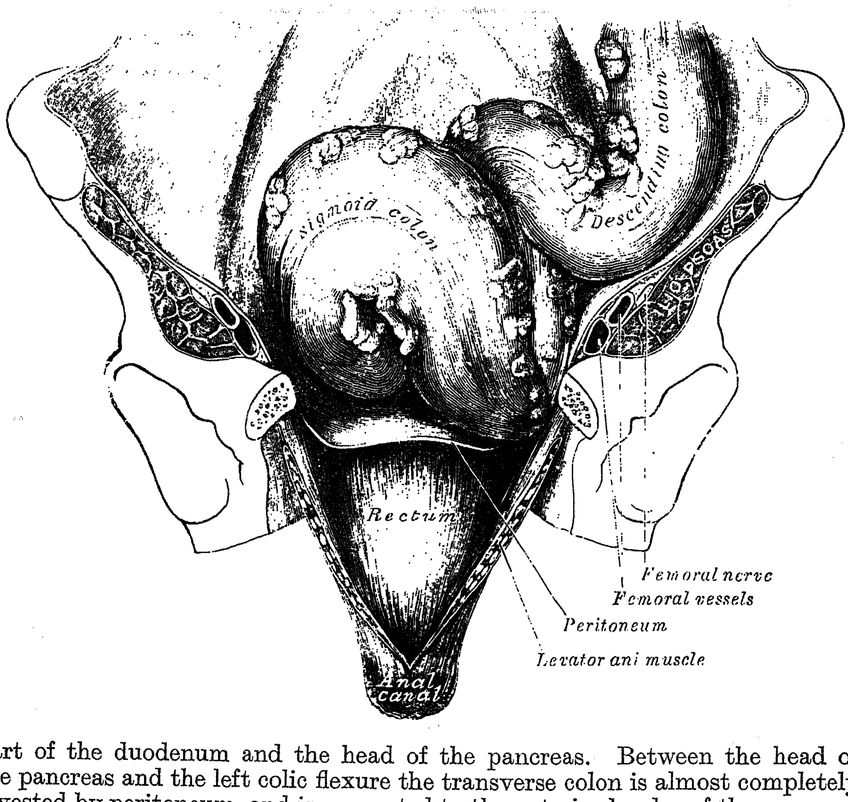
The **colon** is divided into four parts: the ascending, transverse, descending, and sigmoid.

The **ascending colon**, about 15 cm. long, is smaller in calibre than the cæcum. It begins at the cæcum, and ascends to the under surface of the right lobe of the liver, where it is lodged in a shallow depression, the colic impression; here it bends abruptly forwards and to the left, forming the *right colic* (*hepatic*) *flexure* (fig. 1111). It is retained in contact with the posterior wall of the abdomen by the peritoneum, which covers its sides and anterior surface, its posterior surface being connected by loose areolar tissue with the Iliacus, Quadratus lumborum, aponeurotic origin of Transversus abdominis, and with the front of the lower and lateral part of the right kidney. Sometimes the peritoneum completely invests it, and forms a distinct but narrow

mesocolon.* It is in relation, in front, with the convolutions of the ileum and the abdominal parietes.

The **transverse colon** (fig. 1087), about 50 cm. long, begins at the right colic flexure, in the right hypochondriac region, and passing across the abdomen into the left hypochondriac region, curves sharply on itself beneath the lower end of the spleen, forming the *left colic* (*splenic*) *flexure*. In its course across the abdomen it lies in umbilical and epigastric regions, and describes an arch, the concavity of which is usually directed backwards and a little upwards; towards its splenic end there is often an abrupt U-shaped curve which may descend lower than the main curve. The posterior surface of its right extremity is devoid of peritoneum, and is attached by areolar tissue to the descending

FIG. 1127.—The lower part of the descending colon, the sigmoid colon, and the rectum, seen from the front, after the removal of the pubic bones and the bladder.



part of the duodenum and the head of the pancreas. Between the head of the pancreas and the left colic flexure the transverse colon is almost completely invested by peritoneum, and is connected to the anterior border of the pancreas by the *transverse mesocolon*. It is in relation, by its upper surface, with the liver and gall-bladder, the greater cuvature of the stomach, and the lower end of the spleen; by its under surface, with the small intestine; by its anterior surface with the anterior layers of the greater omentum and the abdominal parietes; its posterior surface is in relation with the descending portion of the duodenum, the head of the pancreas, the upper end of the mesentery, the duodenojejunal flexure and some of the coils of the jejunum and ileum.

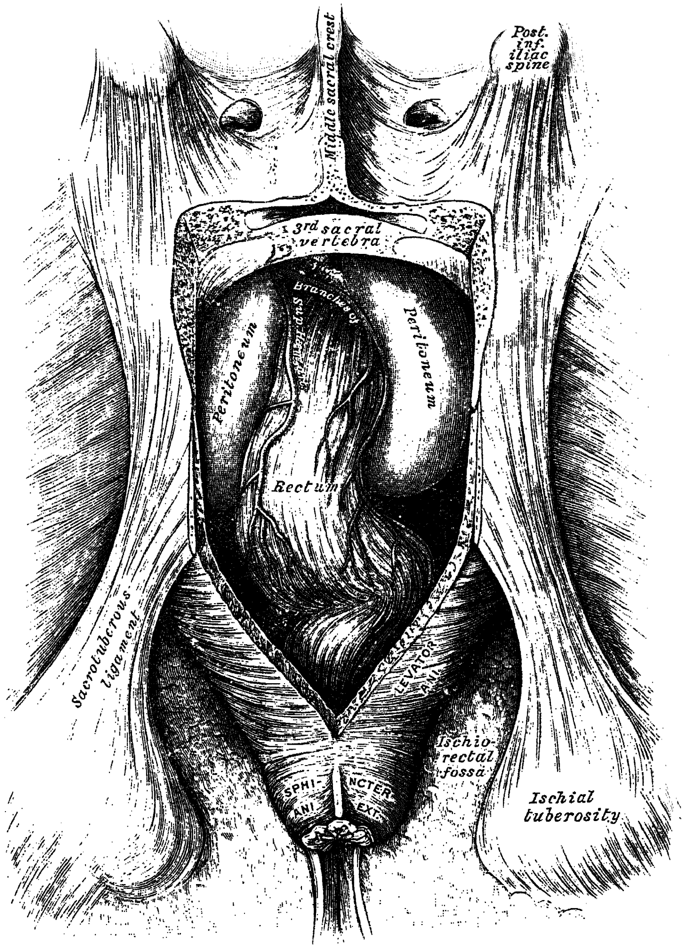
The *left colic or splenic flexure* (fig. 1111) is situated at the junction of the transverse and descending parts of the colon in the left hypochondriac region, and is in relation with the lower end of the spleen and the tail of the pancreas; the flexure is so acute that the end of the transverse colon usually lies in

* Treves examined one hundred subjects, and found that in fifty-two there was neither an ascending nor a descending mesocolon; in fourteen both were present; while in twelve there was an ascending, and in twenty-two a descending, mesocolon. It follows, therefore, that in performing lumbar colotomy a mesocolon may be expected upon the left side in 36 per cent. of all cases, and on the right in 26 per cent.—*The Anatomy of the Intestinal Canal and Peritoneum in Man*, 1885, p. 55.

contact with the front of the descending colon. The left colic flexure lies at a higher level than, and on a plane posterior to, the right colic flexure, and is attached to the Diaphragm, opposite the tenth and eleventh ribs, by a peritoneal fold, named the *phrenicocolic ligament*, which assists in supporting the lower end of the spleen (p. 1144).

The **descending colon**, about 25 cm. long, passes downwards through the left hypochondriac and lumbar regions and in front of the lower part of the left kidney. At the lower end of the kidney it turns medialwards towards the

FIG. 1128.—The posterior aspect of the rectum. Exposed by removing the lower part of the sacrum and the coccyx.



lateral border of the Psoas major, and descends, in the angle between Psoas major and Quadratus lumborum, to the crest of the ilium; it then curves downwards and medialwards in front of the Iliacus and Psoas major, and ends in the sigmoid colon at the superior aperture of the lesser pelvis.* The peritoneum covers its anterior surface and sides, while its posterior surface is connected by areolar tissue with the lower and lateral part of the left kidney, the aponeurotic origin of the Transversus abdominis, the Quadratus lumborum, the Iliacus and the Psoas major (1111, 1127). It is smaller in calibre, more deeply placed, and more frequently covered with peritoneum on its posterior surface, than the ascending colon (p. 1166*). In front of it are some coils of small intestine.

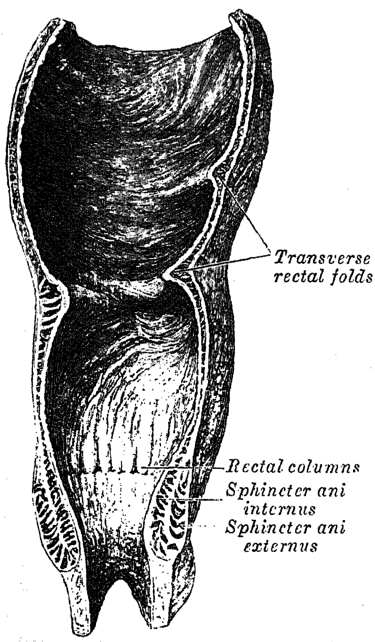
* The descending colon is sometimes described as ending at the level of the iliac crest, the part between that level and the superior aperture of the lesser pelvis being named the *iliac colon.*

The **sigmoid colon** (sometimes called the *pelvic colon*) (fig. 1127) begins at the superior aperture of the lesser pelvis, where it is continuous with the descending colon; it forms a loop which varies greatly in length, but averages about 40 cm., and normally lies within the pelvis. The loop consists of three parts; the first part descends in contact with the left pelvic wall; the second crosses the pelvic cavity, between the rectum and bladder in the male, and the rectum and uterus in the female, and may come into contact with the right pelvic wall; the third arches backwards and reaches the middle line at the level of the third piece of the sacrum, where it bends downward and ends in the rectum. The sigmoid colon is completely surrounded by peritoneum, which forms a mesentery, the *sigmoid mesocolon* (p. 1144); this diminishes in length from the centre towards the ends of the loop, where it disappears, so that the loop is fixed at its junctions with the descending colon and rectum, but enjoys a considerable range of movement in its central portion. *Behind* the sigmoid colon are the external iliac vessels, the left Piriformis, and left sacral plexus of nerves; in *front* of it are some coils of the small intestine which separate it from the bladder in the male, and from the uterus in the female.

The position and shape of the sigmoid colon vary very much, and depend on (*a*) its length; (*b*) the length and freedom of its mesocolon; (*c*) the condition of distension; when distended it rises out of the pelvis into the abdominal cavity, and when empty it sinks again into the pelvis; (*d*) the condition of the rectum and bladder (and the uterus, in the female); when these organs are distended the sigmoid colon tends to rise, and conversely.

The **rectum** (figs. 1127, 1128) is continuous above with the sigmoid colon, whilst below it ends in the anal canal. From its origin at the level of the third sacral vertebra it passes downwards, lying in the sacrococcygeal curve, and extends for 2 or 3 cm. in front of, and a little below, the tip of the coccyx, as far as the apex of the prostate. It then bends sharply backwards into the anal canal. It therefore presents two anteroposterior flexures: an upper or *sacral flexure* with its convexity backwards, and a lower or *perinæal flexure*, with its convexity forwards. Two lateral curves are also described, one convex to the right opposite the junction of the third and fourth sacral vertebræ, and the other to the left, opposite the sacrococcygeal articulation; they are, however, of little importance. The rectum is about 12 cm. long, and at its commencement its calibre is similar to that of the sigmoid colon, but near its termination it is dilated to form the *rectal ampulla*. It has no sacculations comparable to those of the colon, but when the lower part of it is contracted its mucous membrane is thrown into a number of folds, which are longitudinal in direction and are effaced by the distension of the gut. Besides these there are certain permanent *transverse folds* (plicæ transversales recti) of a semilunar shape, known as *Houston's valves* (fig. 1129). There are usually three of these transverse folds, but sometimes four or five, and occasionally only two, are present. One is situated near the commencement of the rectum, on the right side; a second extends inwards from the left side of the tube opposite the middle of the sacrum; a third, the largest and most constant, projects backwards from the fore part of the rectum, opposite the fundus of the urinary bladder. When a fourth is present, it is

FIG. 1129.—A coronal section through the rectum and anal canal.



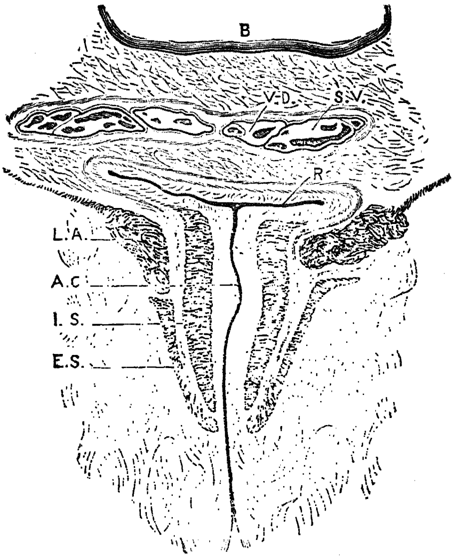
situated nearly 2·5 cm. above the anus on the left and posterior wall of the tube. These folds are about 12 mm. in width and contain some of the circular fibres of the gut. In the empty state of the intestines they overlap each other, as Houston remarks, so effectually as to require considerable manœuvring to conduct a bougie or the finger along the canal. Their use seems to be 'to support the weight of fæcal matter, and prevent its urging towards the anus, where its presence always excites a sensation demanding its discharge.' *

The peritoneum is related to the upper two-thirds of the rectum, covering at first its front and sides, but lower down its front only; from the latter it is reflected on to the seminal vesicles in the male and the posterior vaginal wall in the female.

The level at which the peritoneum is reflected from the rectum to the viscus in front of it is higher in the male than in the female. In the former the height of the rectovesical excavation is about 7·5 cm. (i.e. the height to which an ordinary index finger can reach) from the anus. In the female the height of the recto-uterine excavation is about 5·5 cm. from the anal orifice. The lower part of the rectum is surrounded by a dense tube of fascia which consists of a localised thickening and compression of the extraperitoneal connective tissue; this fascial tube is loosely attached to the rectal wall by areolar tissue, in order to allow of distension of the viscus.

Relations of the rectum.—The upper part of the rectum is in relation, *behind*, with the superior hæmorrhoidal vessels, the left Piriformis and the left sacral plexus of nerves, which separate it from the pelvic surfaces of the sacral vertebræ; its lower part lies on the sacrum, coccyx, and Levatores ani; it is attached to the sacrum along the lines of the sacral foramina by connective tissue which surrounds the sacral nerves and the branches of the superior hæmorrhoidal vessels passing to the bowel. *In front* of its upper part, in the male, is the recto-vesical excavation, in the female, the recto-uterine excavation, of the peritoneum. The excavations contain some convolutions of the small intestine, and frequently the sigmoid colon. Below the recto-vesical excavation in the male the anterior surface of the rectum is in relation with the triangular portion of the fundus of the bladder, the vesiculæ seminales, and ductus deferentes, and more anteriorly with the posterior surface of the prostate; below the recto-uterine excavation in the female, it is in relation with the posterior wall of the vagina.

Fig. 1130.—A coronal section through the anal canal. (Symington.)



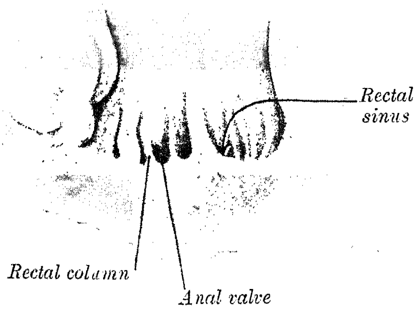
A.C. Anal canal. B. Cavity of urinary bladder. E.S. Sphincter ani externus. I.S. Sphincter ani internus. L.A. Levator ani. R. Second part of rectum. S.V. Seminal vesicle. V.D. Ductus deferens.

The **anal canal** (pars analis recti) (fig. 1130) begins at the level of the apex of the prostate, is directed downwards and backwards, and ends at the anus. It forms an angle with the lower part of the rectum, and is from 2 to 3 cm. long. It has no peritoneal covering, but is invested by the Sphincter ani internus, supported by the Levatores ani, and surrounded at its termination by the Sphincter ani externus. In the empty condition it presents the appearance of an antero-posterior longitudinal slit. Behind it, is a mass of muscular and fibrous tissue,

* Paterson (*Journal of Anatomy and Physiology*, vol. xliii.) utilised the third fold for the purpose of dividing the rectum into an upper and a lower portion; he considered the latter 'to be just as much a duct as the narrower anal canal below,' and maintained that, under normal conditions, it does not contain fæces except during the act of defæcation.

the *anococcygeal body* (Symington); in front of it, in the male, but separated from it by connective tissue, are the membranous portion and bulb of the urethra, and the fascia of the urogenital diaphragm; and in the female it is separated from the lower end of the vagina by a mass of muscular and fibrous tissue, named the *perinæal body*.

FIG. 1131.—The anterior of the anal canal of a new-born child.



The upper half of the anal canal is lined by mucous membrane which presents from six to ten vertical folds known as the *rectal columns* (*Morgagni*). These columns are usually well marked in the new-born child (fig. 1131), but are often ill-defined in the adult. They are produced by infoldings of the mucous membrane and of some of the longitudinal muscular tissue, and each contains a small artery and vein. They are separated from one another by furrows, and end below in small crescentic valve-like folds, termed *anal valves*; these valves join together the lower ends of the rectal columns, and outside each valve is a small pouch or *rectal sinus*.

The lower half of the anal canal is lined by skin which exhibits a series of folds extending upwards from the anus towards the rectal columns. The junction of the skin and mucous membrane is indicated by a white line which is somewhat wavy 'owing to the interlocking of the cutaneous and mucous folds' (Symington).

The **anus** or **anal orifice** is the lower aperture of the anal canal, and is situated in front of the apex of the coccyx in the cleft between the buttocks. The skin surrounding it is thrown into a series of folds which converge towards the orifice and are continued upwards into the lower part of the anal canal.

Structure of the colon.—The large intestine has four coats: serous, muscular, areolar, and mucous.

The *serous coat* is derived from the peritoneum, and invests the different portions of the large intestine to a variable extent. The cæcum is usually completely covered by the serous membrane, but in about 5 per cent. of cases the upper part of the posterior surface is uncovered. The ascending and descending parts of the colon are usually covered only in front and at the sides, a variable amount of the posterior surface being uncovered. The transverse colon is invested with the exception of (*a*) the posterior surface of that part which lies in front of the duodenum and the head of the pancreas, and (*b*) along the lines of attachment of the greater omentum and transverse mesocolon. The sigmoid colon is entirely surrounded. The upper part of the rectum is covered on its anterior surface and sides; the middle part on its anterior surface only; while the lower 5 cm. of the rectum, and the anal canal are devoid of any serous covering. In the course of the colon the peritoneal coat is thrown into a number of small pouches filled with fat, called *appendices epiploicæ*. They are most numerous on the transverse colon.

The *muscular coat* consists of an external longitudinal, and an internal circular layer of non-striped muscular fibres.

The *longitudinal fibres* do not form a continuous layer over the whole surface of the large intestine. In the cæcum and colon they are collected into three longitudinal bands (*tæniæ coli*), each of about 12 mm. in width; one, the *tænia mesocolica*, is placed along the attached border of the intestine; the second and largest, the *tænia omentalis*, corresponds, along the arch of the colon, with the attachment of the greater omentum, but is placed anteriorly in the ascending, descending, and sigmoid parts of the colon; the third, the *tænia libera*, is found on the medial sides of the ascending and descending parts of the colon, and on the under surface of the transverse colon. These bands are shorter than the other coats of the intestine, and serve to produce the sacculi which are characteristic of the cæcum and colon; accordingly, when they are dissected off, the tube can be lengthened, and its sacculated character becomes lost. In the sigmoid colon the longitudinal fibres become more scattered; and round the rectum they spread out and form a layer, which completely encircles this portion of the gut, but is thicker on the anterior and posterior surfaces, where it forms two bands. In addition, two fasciculi of plain muscular tissue arise from the front of the second and third coccygeal vertebræ, and

pass downwards and forwards to blend with the longitudinal muscular fibres on the posterior wall of the anal canal. These are known as the *Rectococcygeal muscles*.

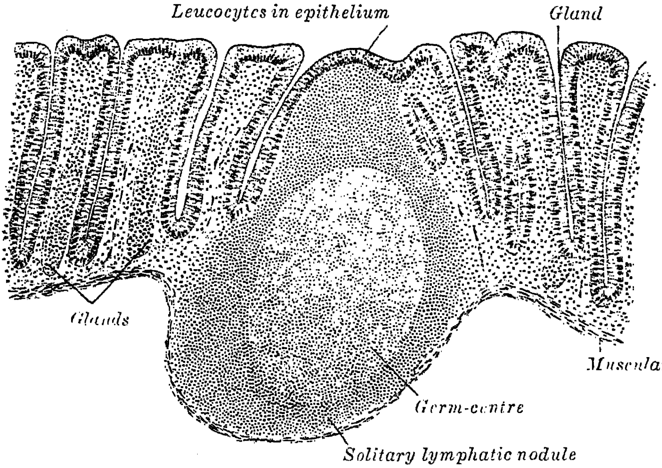
The *circular fibres* form a thin layer over the cæcum and colon, being especially accumulated in the intervals between the sacculi ; in the rectum they form a thick layer, and in the anal canal they become numerous, and constitute the Sphincter ani internus.

The *areolar coat* connects the muscular and mucous layers closely together.

The *mucous membrane* of the cæcum and colon is pale, smooth, destitute of villi, and raised into numerous crescentic folds which correspond with the intervals between the sacculi; that of the rectum is thicker, of a darker colour, more vascular, and connected loosely with the muscular coat.

As in the small intestine, the mucous membrane (fig. 1132) consists of a muscular layer, the muscularis mucosæ; a quantity of retiform tissue in which the vessels ramify; a basement-membrane, and an epithelium which is of the columnar variety and resembles the epithelium found in the small intestine. The mucous membrane of the large intestine presents for examination glands and solitary lymphatic nodules.

FIG. 1132.—A section through the mucous membrane of the human rectum. ×60. (Sobotta.)



The *glands* of the great intestine are minute tubular prolongations of the mucous membrane arranged perpendicularly to its surface; they are longer, more numerous, and placed in much closer apposition than those of the small intestine; and they open by minute rounded orifices upon the surface, giving it a cribriform appearance. Each gland is lined by short columnar epithelium, the majority of the cells being goblet-cells.

The *solitary lymphatic nodules* (fig. 1132) of the large intestine are most abundant in the cæcum and vermiform process, but are irregularly scattered also over the rest of the large intestine. They are similar to those of the small intestine.

Vessels and Nerves.—The *arteries* supplying the colon are derived from the colic and sigmoid branches of the mesenteric arteries. They give off large branches, which ramify between and supply the muscular coats, and after dividing into small vessels in the submucous tissue, pass to the mucous membrane. The rectum is supplied by the superior hæmorrhoidal branch of the inferior mesenteric, and the anal canal by the middle hæmorrhoidal from the hypogastric, and the inferior hæmorrhoidal from the internal pudendal artery. The superior hæmorrhoidal, the continuation of the inferior mesenteric, divides into two branches, which run down either side of the rectum to within about 12·5 cm. of the anus; they here divide into a number of branches, which pierce the muscular coat and descend between it and the mucous membrane in the rectal columns as far as the Sphincter ani internus, where they anastomose with the other hæmorrhoidal arteries and form a series of loops around the anus. The *veins* of the rectum commence in a plexus of vessels which surrounds the anal canal. In the vessels forming this plexus are small saccular dilatations just within the margin of the anus; from the plexus about six vessels of considerable size are given off. These ascend between the muscular and mucous coats for about 12·5 cm., running parallel to each other; they then pierce the muscular coat, and, by their union, form a single trunk, the superior hæmorrhoidal vein. This arrangement is termed the *hæmorrhoidal plexus*; it communicates with the tributaries of the middle and inferior hæmorrhoidal veins, at its commencement, and thus a communication is established between the systemic and portal circulations. The *nerves* are derived from the second, third and fourth sacral nerves, and from the sympathetic, through the

pelvic plexuses. They are distributed in a similar way to those found in the small intestine.

The *lymphatics* of the large intestine are described on pp. 770, 771.

Applied Anatomy.—The small intestine is much exposed to injury, but, in consequence of its elasticity and the ease with which one coil glides over another, it is not so frequently ruptured as would otherwise be the case. Any part of it may be ruptured, but probably the most common situation is the horizontal portion of the duodenum, on account of its being more fixed than other portions of the bowel, and because it is situated in front of the bodies of the vertebræ, so that if this portion of the intestine is struck by a sharp blow, as from the kick of a horse, it is unable to glide out of the way, but is compressed against the bone and so lacerated. Wounds of the intestine sometimes occur. If the wound is a small puncture, under, it is said, 6 mm. in length, no extravasation of the contents of the bowel takes place; the mucous membrane becomes everted and plugs the little opening. The small intestine, and most frequently the ileum, may become strangulated by internal bands, or through apertures, normal or abnormal. The bands may be formed in several different ways; they may be old peritoneal adhesions from previous attacks of peritonitis; or an adherent omentum from the same cause; or the band may be formed by Meckel's diverticulum, which has contracted adhesions at its distal extremity; or it may be the result of the abnormal attachment of some normal structure, as the adhesion of two appendices epiploicæ, or an adherent vermiform process or uterine tube. Intussusception, most commonly an invagination of the small intestine into the large, may take place; it may attain great size, and it is possible in these cases to find the colic valve projecting from the anus. Stricture, the impaction of foreign bodies, and twisting of the gut (*volvulus*) may also lead to intestinal obstruction.

Resection of a portion of the intestine may be required in cases of gangrene; for the removal of new growth in the bowel; in dealing with artificial anus; and in cases of rupture. The operation is termed *enterectomy*, and is performed as follows: the abdomen having been opened and the amount of bowel requiring removal having been determined upon, the intestine must be clamped on either side of this portion in order to prevent the escape of any of its contents during the operation. The portion of the bowel is then separated above and below by means of scissors. If the portion resected is small, it may be simply removed from the mesentery at its attachment, and the bleeding vessels tied; but if it be large it will be necessary to take away a triangular piece of the mesentery, and, having secured the vessels, suture the cut edges of this structure together. In doing this, care must be taken not to leave any intestine projecting beyond the line of the section of the mesentery, as gangrene is very likely to occur in the projecting part if this is done. The surgeon then proceeds to unite the cut ends of the bowel by end-to-end anastomosis. There are many ways of doing this, but they may be divided into two classes, one where the anastomosis is made by means of some mechanical appliance, such as Murphy's button, or one of the forms of decalcified bone bobbin; and the other, where the operation is performed by suturing the ends of the bowel in such a manner that the peritoneum covering the two divided ends is brought into contact, so that speedy union may ensue.

The vermiform process is very liable to become inflamed, because it contains a relatively large amount of lymphoid tissue which is prone to bacterial infection. In many cases the inflammation is set up by the impaction in it of a solid mass of fæces or a foreign body, or by the inspissation of its mucous secretion in catarrhal conditions. The inflammation may result in ulceration and perforation, or if very acute in gangrene of the process. These conditions generally require immediate operative interference, and in chronic cases with recurring attacks of inflammation it is always advisable to remove this diverticulum of the bowel. In incising the abdominal wall for this operation, the muscles should be split in the direction of their fibres, rather than cut across, in order to prevent subsequent weakening of the abdominal parietes and the occurrence of a ventral hernia. After the process has been removed it is better to suture the planes of the abdominal wall separately.

In external hernia the ileum is the portion of bowel most frequently herniated. When a part of the large intestine is involved it is usually the cæcum, and this may occur even on the left side. In some few cases the vermiform process has been the part implicated in strangulated hernia.

Chronic ulcer of the duodenum is sometimes met with, probably produced by the same causes as chronic ulcer of the stomach. It may perforate and set up a rapidly fatal peritonitis, or it may open into the gastroduodenal artery and cause death from hæmorrhage. An acute ulcer sometimes, but rarely, follows extensive burns of the skin.

The calibre of the large intestine gradually diminishes from the cæcum, which has the greatest diameter of any part of the bowel, to the point of junction of the sigmoid colon with the rectum. At or a little below this point stricture most commonly occurs, and diminishes in frequency as one proceeds upwards to the cæcum. When distended by some obstruction low down, the outline of the large intestine can be defined throughout nearly the whole of its course—all, in fact, except the right and left colic flexures, which are more deeply placed; the distension is most obvious in the flanks and on the front of the abdomen just above the umbilicus. The cæcum, however, is the portion of the bowel which becomes most distended. It may assume enormous dimensions, and may give way from the distension, leading to rapidly fatal peritonitis. The right colic flexure and the

side of the aorta, between the duodenojejunal junction and the root of the transverse mesocolon. It is present in about 20 per cent. of bodies, and has an average depth of from 2 cm. to 3 cm. Its orifice is directed forwards.

2. *Cæcal fossæ.*—There are three principal pouches or recesses in the neighbourhood of the cæcum : (*a*) The *superior ileocæcal fossa* (fig. 1098) is formed by a fold of peritoneum, the superior ileocæcal fold, arching over the branch of the ileocolic artery which supplies the ileocolic junction. The fossa is a narrow chink situated between the mesentery of the small intestine, the ileum, and the small portion of the cæcum behind. (*b*) The *inferior ileocæcal fossa* (fig. 1098) is situated behind the angle of junction of the ileum and cæcum. It is formed by the *inferior ileocæcal fold* of peritoneum (bloodless fold of Treves), the upper border of which is fixed to the ileum, opposite its mesenteric attachment, while the lower border joins the mesenteriole of the vermiform process, and sometimes the process itself. Between this fold and the mesenteriole of the vermiform process is the inferior ileocæcal fossa. It is bounded above by the posterior surface of the ileum and the mesentery ; in front by the inferior ileocæcal fold, and behind by the upper part of the mesenteriole of the vermiform process. (*c*) The *cæcal fossa* (fig. 1099) is situated immediately behind the cæcum, which has to be raised to bring it into view. It varies much in size and extent. In some cases it is sufficiently large to admit the index finger, and extends upwards behind the ascending colon in the direction of the kidney ; in others it is merely a shallow depression. It is bounded on the right by the cæcal fold, which is attached by one edge to the abdominal wall from the lower border of the kidney to the iliac fossa, and by the other to the posterolateral aspect of the colon. In some instances additional fossæ, the *retrocæcal fossæ,* are present.

3. The *intersigmoid fossa* is constant in the fœtus and during infancy, but may disappear as age advances. Upon drawing the sigmoid colon upwards, the left surface of the sigmoid mesocolon is exposed, and behind it will be seen a funnel-shaped recess of the peritoneum, lying on the external iliac vessels, in the interspace between the Psoas and Iliacus muscles. This is the orifice leading to the intersigmoid fossa, which lies behind the sigmoid mesocolon, and in front of the parietal peritoneum. The fossa varies in size ; in some instances it is a mere dimple, in others it will admit the whole of the index finger.

Applied Anatomy.—Any of these fossæ may be the site of a ‘ retroperitoneal ’ hernia. The cæcal fossæ are of especial interest, because hernia of the vermiform process frequently takes place into one of them, and may there become strangulated. The presence of these pouches also explains the course which pus has been known to take in cases of perforation of the vermiform process, where it travels upwards behind the ascending colon as far as the Diaphragm.

The Stomach (Ventriculus)

The **stomach** is the most dilated part of the digestive tube, and is situated between the end of the œsophagus and the beginning of the small intestine. It lies in the epigastric, umbilical, and left hypochondriac regions of the abdomen, and occupies a recess bounded by the upper abdominal viscera, and completed in front and on the left side by the anterior abdominal wall and the Diaphragm.

The *shape and position* of the stomach are so greatly modified by changes within itself and in the surrounding viscera that no one form can be described as typical. The chief modifications are determined by (1) the amount of the stomach contents, (2) the stage which the digestive process has reached, (3) the degree of development of the gastric musculature, and (4) the condition of the adjacent intestines ; but there are certain markings more or less common to all (fig. 1100).

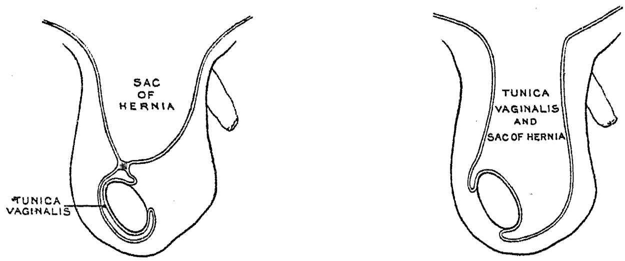
The stomach has two openings, two borders or curvatures, and two surfaces.

Openings.—The opening by which the œsophagus communicates with the stomach is known as the *cardiac orifice,* and is situated on the left of the middle line at the level of the eleventh thoracic vertebra. The short abdominal portion of the œsophagus (*antrum cardiacum*) is conical in shape and curved

but merely that a condition is present which may allow of the descent of the hernia at any moment. As a matter of fact, congenital herniæ frequently do not appear till adult life.

Where the processus vaginalis is occluded at the lower point only, i.e. just above the testis, the intestine descends into the pouch of peritoneum as far as the testis, but is prevented from entering the sac of the tunica vaginalis by the septum which has formed between it and the pouch. This is known as *hernia into the funicular process* or *incomplete congenital* hernia (fig. 1133); it differs from the former in that instead of enveloping the testis it lies above it.

FIG. 1133.—The varieties of oblique inguinal hernia.



Incomplete congenital Complete congenital

In *direct inguinal hernia* the protrusion makes its way through some part of Hesselbach's triangle, either through (*a*) the lateral part, where only extraperitoneal tissue and transversalis fascia intervene between the peritoneum and the aponeurosis of the Obliquus externus; or through (*b*) the inguinal aponeurotic falx which stretches across the medial two-thirds of the triangle between the artery and the middle line. In the former the hernial protrusion escapes from the abdomen on the lateral side of the inguinal falx, pushes before it the peritoneum, extraperitoneal tissue and transversalis fascia, and enters the inguinal canal. It passes along nearly the whole length of the canal and finally emerges from the subcutaneous ring, receiving an investment from the intercrural fascia. The coverings of this form of hernia are similar to those of the oblique form, except that a portion derived from the general layer of transversalis fascia replaces the infundibuliform fascia.

In the second form, which is the more frequent, the hernia is either forced through the fibres of the inguinal falx, or the falx is gradually distended in front of it so as to form a complete investment for it. The intestine then enters the lower end of the inguinal canal, escapes at the subcutaneous ring, lying on the medial side of the cord, and receives additional coverings from the intercrural fascia, the superficial fascia and the integument. The coverings of this form therefore differ from those of the oblique form in that the inguinal falx is substituted for the Cremaster, and the infundibuliform fascia is replaced by a portion of the general layer of the transversalis fascia.

Direct inguinal hernia is of much less frequent occurrence than oblique, and is found more often in men than in women. The main differences in position between it and the oblique form are: (*a*) it is placed over the os pubis and not in the course of the inguinal canal; (*b*) the inferior epigastric artery runs on the lateral or iliac side of the neck of the sac; and (*c*) the spermatic cord lies along its lateral and posterior sides, not directly behind it as in oblique inguinal hernia. A direct hernia is always of the acquired variety.

The seat of stricture in both varieties of direct hernia is usually found either at the neck of the sac or at the subcutaneous ring. In that form which perforates the inguinal falx it may occur at the edges of the fissure through which the gut passes. In all cases of inguinal hernia, whether direct or oblique, it is proper to divide the stricture directly upwards; by cutting in this direction the incision is made parallel to the inferior epigastric artery, and all chance of wounding the vessel is thus avoided.

Femoral hernia.—In femoral hernia the protrusion of the intestine takes place through the femoral ring. As already described (p. 689), this ring is closed by the femoral septum, a partition of modified extraperitoneal tissue; it is therefore a weak spot in the abdominal wall, and especially in the female, where the ring is larger, and where profound changes are produced in the tissues of the abdomen by pregnancy. Femoral hernia is therefore more common in women than in men.

When a portion of intestine is forced through the femoral ring, it carries before it a pouch of peritoneum, which forms the hernial sac. It receives an investment from the extraperitoneal tissue or femoral septum, and descends along the femoral canal, or inner compartment of the sheath of the femoral vessels, as far as the fossa ovalis; at this point it changes its course, being prevented from extending farther down the sheath on account of the narrowing of the latter, and its close contact with the vessels, and also the close

attachment of the superficial fascia and femoral sheath to the lower part of the circumference of the fossa ovalis. The tumour is consequently directed forwards, pushing before it the fascia cribrosa, and then curves upwards over the inguinal ligament and the lower part of the aponeurosis of the Obliquus externus, being covered by the superficial fascia and integument. While the hernia is contained in the femoral canal it is usually of small size, owing to the resisting nature of the surrounding parts, but when it escapes from the fossa ovalis into the loose areolar tissue of the groin it becomes considerably enlarged. The direction taken by a femoral hernia is at first downwards, then forwards and upwards; in the application of taxis for the reduction of a femoral hernia, therefore, pressure should be directed in the reverse order.

The coverings of a femoral hernia from within outwards are: peritoneum, femoral septum, femoral sheath, fascia cribrosa, superficial fascia, and integument. Sir Astley Cooper has dèscribed an investment for femoral hernia under the name of *fascia propria*, lying immediately external to the peritoneal sac but frequently separated from it by some adipose tissue. Surgically it is important to remember the frequent existence of this layer on account of the ease with which an inexperienced operator may mistake the fascia for the peritoneal sac and the contained extraperitoneal fat for omentum, as there is often a great excess of subperitoneal fatty tissue enclosed in the ' fascia propria.' In many cases it resembles a fatty tumour, but on further dissection the true hernial sac will be found in the centre of the mass of fat. The fascia propria is merely a modified femoral septum which has been thickened to form a membranous sheet by the pressure of the hernia.

When the intestine descends along the femoral canal only as far as the fossa ovalis the condition is known as *incomplete* femoral hernia, in contradistinction to the *complete* hernia when it has passed through the fossa ovalis. The small size of the protrusion in the incomplete form of hernia, on account of the firm and resisting nature of the canal in which it is contained, renders it an exceedingly dangerous variety of the disease, from the extreme difficulty of detecting the existence of the swelling, especially in corpulent subjects. The coverings of an incomplete femoral hernia would be from without inwards: integument, superficial fascia, superior cornu of falciform margin of the fossa ovalis, femoral sheath, femoral septum, and peritoneum.

The seat of stricture of a femoral hernia varies: it may be in the peritoneum at the neck of the hernial sac; in the greater number of cases it is at the point of junction of the falciform margin of the fossa ovalis with the free edge of the lacunar ligament; or it may be at the margin of the fossa ovalis. The stricture should in every case be divided in a direction upwards and medialwards for a distance of about 4 mm. to 6 mm. All vessels or other structures of importance in relation to the neck of the sac will thus be avoided.

The pubic tubercle forms an important landmark in serving to differentiate the inguinal from the femoral variety of hernia. The inguinal protrusion is above and medial to the tubercle, while the femoral is below and lateral to it.

There are several details of practical interest in connexion with the mesentery which merit notice. 1. The depth of the mesentery—that is to say, the distance from its parietal to its intestinal attachment—is normally less than 20 cm., generally nearer 15 cm.; but under certain abnormal conditions it may become elongated, and this would appear to favour the occurrence of hernia of the intestine. 2. Not only may the depth of the mesentery be increased, but its point of attachment to the posterior abdominal wall may yield, and descend over the lumbar vertebræ. This condition, which is known under the name of *enteroptosis*, usually occurs in women who have borne many children, and is attended with general relaxation of the abdominal parietes. It produces a characteristic appearance, the abdomen being prominent and pendulous below, while above, it is flattened and constricted. 3. Holes are sometimes present in the mesentery, and these may be congenital, or may be the result of injury. They are of practical importance, since a knuckle of intestine may become herniated into one of them, causing acute strangulation. 4. The lymph-glands contained between the two layers of the mesentery are frequently the seat of tuberculous deposit, especially in children.

Colon.—The colon frequently requires opening in cases of intestinal obstruction, and by some surgeons this operation is performed in cases of cancer of the rectum as soon as the disease is recognised, in the hope that the symptoms may be relieved by removing the irritation produced by the passage of fæcal matter over the diseased surface. The operation of *colostomy* may be performed either in the iliac or lumbar region; but *iliac colostomy* has in the present day entirely superseded the lumbar operation. The main reasons for preferring this operation are that a spur-shaped process of the mesocolon can be formed, which prevents any fæcal matter finding its way past the artificial anus, and the greater ease in maintaining cleanliness. The sigmoid colon being entirely surrounded by peritoneum, a coil can be drawn out of the wound and opened, leaving the attachment of the mesocolon to form a spur, much as it does in an artificial anus caused by sloughing of the intestine after a strangulated hernia, and this prevents any fæcal matter finding its way from the gut above the opening into that below. The operation is performed by making an incision 5 cm. to 7 cm. long through the outermost fibres of the left Rectus abdominis, opposite the anterior superior iliac spine. The peritoneum is opened; the sigmoid colon is now sought, pulled out of the wound, and fixed by passing a glass rod

beneath it, or by suturing the mesocolon close to the gut to the abdominal wall. Later, the protruding coil of intestine is opened, and finally, when firm adhesions have formed, it is cut completely across.

Rectum.—The surgical anatomy of the rectum is of considerable importance. There may be congenital malformations due to arrest of, or imperfection in, development. Thus, there may be no proctodæal invagination (p. 142), and consequently a complete absence of the anus; or the hind-gut may be imperfectly developed, and there may be an absence of the rectum, though the anus is developed; or the proctodæal invagination may not communicate with the termination of the hind-gut from want of solution of continuity in the septum which in early fœtal life exists between the two.

The mucous membrane of the rectum is thick and but loosely connected to the muscular coat beneath, and thus favours prolapse, especially in children. The vessels of the rectum are arranged, as mentioned above, longitudinally, and are contained in the loose cellular tissue between the mucous and muscular coats, and receive no support from surrounding tissues, and this favours varicosity. Moreover, the veins, after running upwards in a longitudinal direction for about 12·5 cm. in the submucous tissue, pierce the muscular coats, and are liable to become constricted at this spot by the contraction of the muscular wall of the gut. In addition to this there are no valves in the superior hæmorrhoidal veins, and the vessels of the rectum are placed in a dependent position, and are liable to be pressed upon and obstructed by hardened fæces. The anatomical arrangement, therefore, of the hæmorrhoidal vessels explains the great tendency to the occurrence of piles. The presence of the Sphincter ani externus is of surgical importance, since it is the constant contraction of this muscle which prevents an ischiorectal abscess from healing, and causes it to become a fistula. Also the reflex contraction of this muscle is the cause of the severe pain complained of in fissure of the anus. The relations of the peritoneum to the bowel are of importance in connexion with the operation of removal of the rectum for malignant disease. This membrane gradually leaves the rectum as it descends into the pelvis; first leaving its posterior surface, then the sides, and then the anterior surface, to become reflected, in the male on to the posterior wall of the bladder, forming the rectovesical excavation, and in the female on to the posterior wall of the vagina, forming the recto-uterine excavation. The rectovesical excavation extends to within 7·5 cm. from the anus. Within recent years much more extensive operations have been done for the removal of cancer of the rectum, and in these the peritoneal cavity has necessarily to be opened. For cases of cancer of the rectum which are too low to be reached by abdominal section, and too high to be removed by the perinæum, Kraske has devised an operation which goes by his name. The patient is placed on his right side and an incision is made from the last piece of the sacrum to the anus. The coccyx is removed, and if necessary a small piece of the sacrum, and the edges of the wound being now forcibly drawn outwards, a considerable length of the rectum is brought into view, and the diseased portion is removed.

The loose connective tissue round the rectum, above the Levator ani, is occasionally the site of an abscess, the active focus of which, however, may be located elsewhere. This form of abscess may be described as the *superior pelvirectal*; it is placed above the pelvic diaphragm but beneath the peritoneum. The acute variety is generally due to ulceration or perforation of the bowel (possibly produced by a foreign body) above the level of attachment of the Levator ani. The abscess may also occur above a stricture (simple or malignant) of the rectum; occasionally it arises from suppuration around the prostate, and more rarely follows abscess of the vesiculæ seminales. Chronic abscesses also appear in the same region either from caries of the anterior surface of the sacrum or from caseation of the presacral lymph-glands, whilst in other cases an abscess finds its way down into the pelvis from disease of the anterior surfaces of the bodies of the lumbar vertebræ. For abscess in the ischiorectal fossa, see p. 486.

The Pancreas

The **pancreas** is a compound racemose gland, analogous in its structure to the salivary glands, but softer, and less compactly arranged. It is irregularly prismoid in shape, and from 12 cm. to 15 cm. long. Its broad, right extremity is called the *head*, and is connected to the main portion, or *body*, by a slightly constricted part, the *neck*; its narrow, left extremity forms the *tail*. It is placed across the posterior wall of the abdomen, at the back of the epigastric and left hypochondriac regions.

Relations (figs. 1134 to 1136).—The **head**, flattened from before backwards, is lodged within the curve of the duodenum. Its upper border is overlapped by the superior part of the duodenum; the other borders are grooved to receive the adjacent margin of the duodenum which they overlap in front and behind to a variable extent. The angle of junction of the lower and left lateral borders forms a prolongation termed the *uncinate process*, which projects to the left behind the superior mesenteric vessels. In or near the groove between

the duodenum and the right lateral and lower borders anteriorly are the anastomosing superior and inferior pancreaticoduodenal arteries; the bile-duct descends behind the head, close to its right border.

Fig. 1134.—A transverse section through the abdomen at the level of the middle of the first lumbar vertebra. (Braune.)

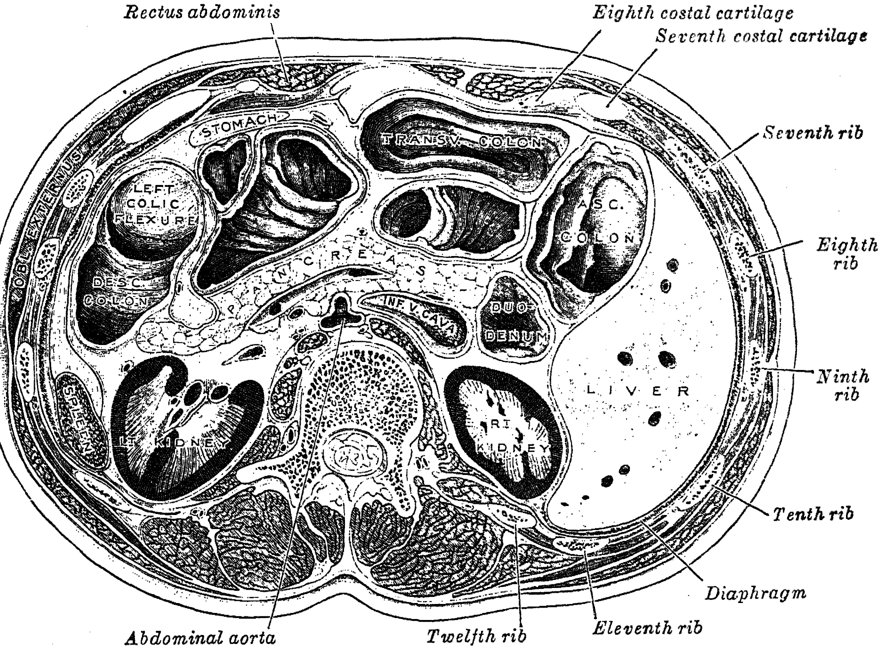
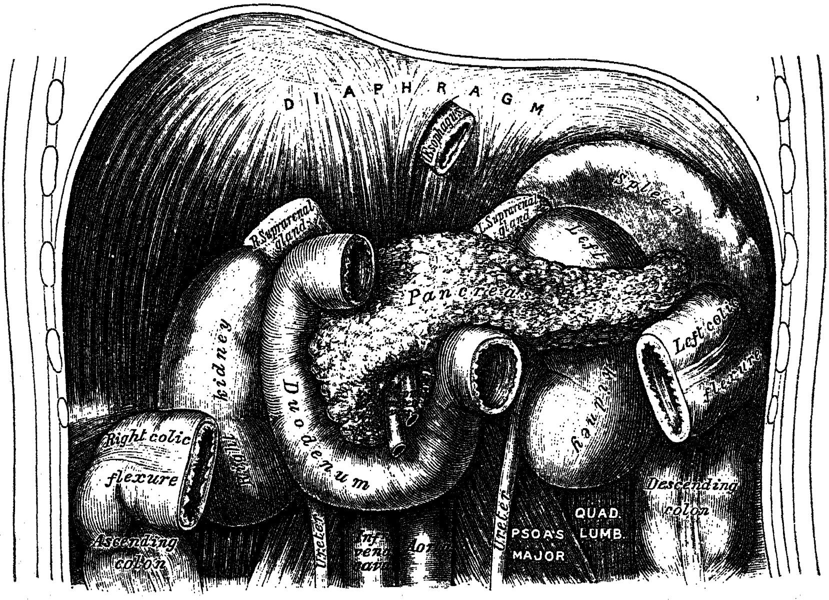


Fig. 1135.—The pancreas and duodenum. Anterior aspect.

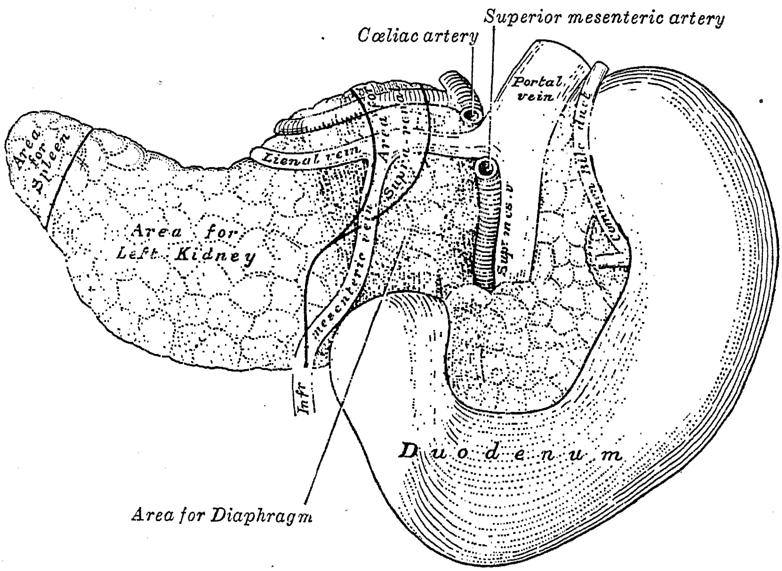


Anterior surface.—From the upper part of the front of the head of the pancreas, the neck juts forwards, upwards and towards the left, to be continued into the body of the pancreas. The boundary between the head and neck,

on the right side, is a groove for the gastroduodenal artery; on the left side a deep notch, *incisura pancreatis*, intervenes between the head and the neck and body, and in this notch the superior mesenteric and lienal veins unite to form the portal vein. Below and to the right of the neck the anterior surface of the head is in contact with the transverse colon, only areolar tissue intervening, while still lower the surface is covered by peritoneum continuous with the inferior layer of the transverse mesocolon, and is in contact with coils of the jejunum. Below and to the left of the neck is the uncinate process which is crossed by the superior mesenteric vessels.

Posterior surface.—The posterior surface of the head of the pancreas is in relation with the inferior vena cava, the renal veins, the right crus of the Diaphragm, and the aorta. The bile-duct either lies in a groove on the posterior surface of the head of the pancreas or in a canal in its substance (McConnell *).

FIG. 1136.—The pancreas and duodenum. Posterior aspect. (From a model by His.)



The **neck**, about 2 cm. long, is confluent below and to the right with the anterior surface of the head; it extends upwards and to the left, and merges imperceptibly with the body. It is a somewhat ridge-like part of the pancreas, accentuated by two vascular depressions; below and to the left is the deep notch containing the superior mesenteric vessels, while above and to the right is a groove in which the lower end of the gastroduodenal artery and the superior pancreaticoduodenal artery, are lodged. Its anterior surface supports the pylorus; its posterior surface is in relation with the beginning of the portal vein.

The **body** is somewhat prismoid in shape, and has three surfaces: anterior, posterior, and inferior.

The *anterior surface* is concave, and is directed forwards and upwards; it is separated from the stomach by the omental bursa.

The *posterior surface* is devoid of peritoneum, and is in contact with the aorta, the lienal vein, the left kidney and its vessels, the left suprarenal gland, the origin of the superior mesenteric artery, and the left crus of the Diaphragm.

The *inferior surface* is narrow on the right but broader on the left, and is covered by peritoneum; it lies upon the duodenojejunal flexure and on some coils of the jejunum; its left extremity rests on the left colic flexure.

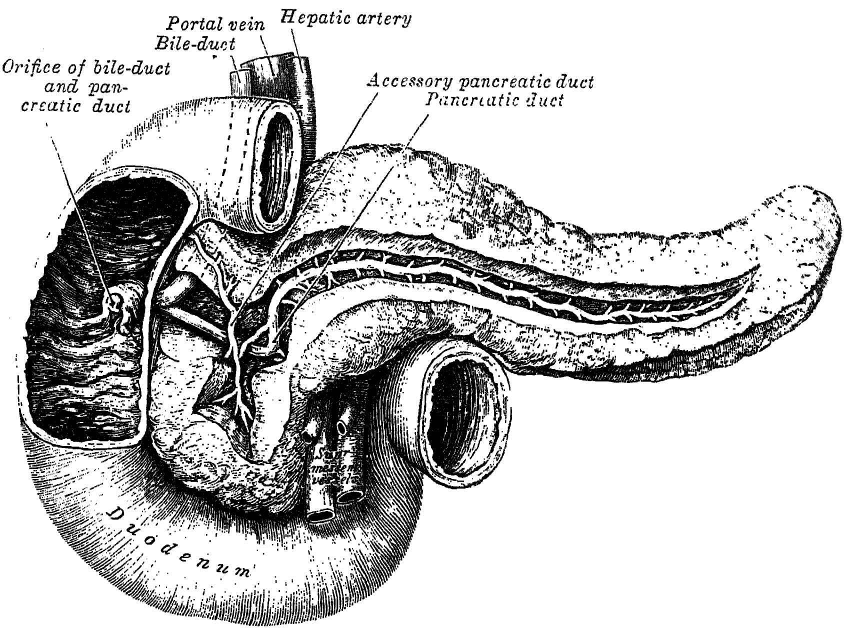
* *Journal of Anatomy and Physiology*, vol. xlix.

The *superior border* is blunt and flat to the right; narrow and sharp to the left, near the tail. It is in relation with the cœliac artery, from which the hepatic artery courses to the right just above the gland, while the lienal artery runs towards the left in a groove along this border. A process, the *tuber omentale*, usually projects from the right end of the superior border above the level of the lesser curvature of the stomach, and is in contact with the posterior surface of the lesser omentum.

The *anterior border* separates the anterior from the inferior surface, and along this border the two layers of the transverse mesocolon diverge from one another: one passing upwards over the anterior surface, the other backwards over the inferior surface.

The *inferior border* separates the posterior from the inferior surface; the superior mesenteric vessels emerge under its right extremity.

FIG. 1137.—The pancreatic duct.



The **tail** is narrow, and usually lies in contact with the inferior part of the gastric surface of the spleen.

Birmingham described the body of the pancreas as projecting forwards as a prominent ridge into the abdominal cavity and forming part of a bed or shelf on which the stomach lies. 'The portion of the pancreas to the left of the middle line has a very considerable anteroposterior thickness; as a result the anterior surface is of considerable extent; it looks strongly upwards, and forms a large and important part of the shelf. As the pancreas extends to the left towards the spleen it crosses the upper part of the kidney, and is so moulded on to it that the top of the kidney forms an extension inwards and backwards of the upper surface of the pancreas and extends the bed in this direction. On the other hand, the extremity of the pancreas comes in contact with the spleen in such a way that the plane of its upper surface runs with little interruption upwards and backwards into the concave gastric surface of the spleen, which completes the bed behind and to the left, and, running upwards, forms a partial cap for the wide end of the stomach.' *

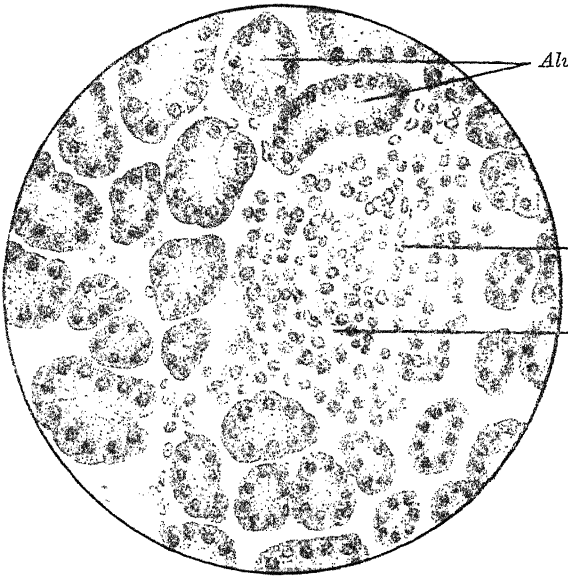
The **pancreatic duct** (ductus Wirsungi) traverses the pancreas from left to right, lying nearer its posterior than its anterior surface (fig. 1137). It begins by the junction of the small ducts of the lobules situated in the tail of the pancreas, and, running from left to right through the body, receives the ducts of the various lobules composing the gland. Considerably augmented

* *Journal of Anatomy and Physiology*, vol. xxxi.

in size, it reaches the neck, and turning downwards, backwards, and to the right, comes into relation with the bile-duct, which lies to its right side ; leaving the head of the gland, it passes very obliquely through the mucous and muscular coats of the duodenum, and ends by an orifice, common to it and the bile-duct upon the summit of the duodenal papilla (p. 1155), situated at the medial side of the descending portion of the duodenum, from 7 cm. to 10 cm. beyond the pylorus. The pancreatic duct, near the duodenum, is about the size of an ordinary quill. Sometimes the pancreatic duct and the bile-duct open separately into the duodenum. Frequently there is an additional duct, which communicates with the pancreatic duct in the neck of the pancreas and opens into the duodenum about 2 cm. above the duodenal papilla. It receives the ducts from the lower part of the head, and is known as the *accessory pancreatic duct* (ductus Santorini) (fig. 1137).

Structure (fig. 1138).—In structure, the pancreas resembles the salivary glands. It differs from them, however, in certain particulars, and is looser and softer in its texture. It is not enclosed in a distinct capsule, but is surrounded by areolar tissue, which dips

FIG. 1138.—A section through a part of the human pancreas. Stained with hæmatoxylin and eosin. × 400.



into its interior, and connects together the various lobules of which it is composed. Each lobule, like the lobules of the salivary glands, consists of one of the ultimate ramifications of the main duct, ending in a number of alveoli, which are tubular and somewhat convoluted. The minute ducts (intercalary ducts) connected with the alveoli are narrow and lined with flattened cells. In some animals spindle-shaped cells occupy the centre of the alveolus and are known as *centro-acinar cells*. The true secreting cells which line the wall of the alveolus are columnar in shape and present two zones ; an outer, clear and faintly striated, next the basement-membrane, and an inner, which contains secretory granules. In hardened specimens the outer zone stains deeply with basic dyes, whereas the inner zone stains slightly. During activity the granular zone gradually diminishes in size ; during the resting stages it gradually increases until it forms nearly three-fourths of the cell. In some of the secreting cells of the pancreas is a spherical mass, staining more easily than the rest of the cell ; this is termed the *paranucleus*, and is believed to be derived from the nucleus. Between the alveoli are found, in certain parts, collections of cells, which are termed *interalveolar cell-islets*, or islands of Langerhans. The cells of these stain lightly with hæmatoxylin or carmine, and are more or less polyhedral in shape, forming a network in which many capillaries ramify. There are two main types of cell in the islets, distinguished as A-cells and B-cells according to the special staining reactions of the granules they contain. The cell-islets are believed to produce the internal secretion of the pancreas which is necessary for carbohydrate metabolism.

The wall of the pancreatic duct is thin, consisting of two coats, an external fibrous and an internal mucous; the latter is smooth, lined by columnar epithelium, and furnished near its termination with a few scattered follicles.

Vessels and Nerves.—The *arteries of the pancreas* are derived from the lienal artery, and from the pancreaticoduodenal branches of the hepatic and superior mesenteric arteries. Its *veins* open into the lienal and superior mesenteric veins. Its *lymphatic vessels* are described on p. 771. Its *nerves*, derived from the vagus and splanchnic nerves, reach it through the lienal plexus.

Applied Anatomy.—Inflammation of the pancreas has of late years received considerable attention. It appears to be due to infection of the pancreatic ducts by micro-organisms from the duodenum in cases of gastroduodenal catarrh, or from the biliary passages in which a gall-stone is lodged. Acute cases usually terminate fatally and are frequently of the hæmorrhagic type; chronic inflammation of the pancreas produces few symptoms of disease unless it is extensive, when attacks of abdominal pain, loss of appetite, progressive weakness and wasting, and the passage of whitish fatty motions, are likely to follow. Extensive fibrosis of the pancreas is also one of the commonest lesions found post-mortem in cases of diabetes mellitus. Cysts of the pancreas are sometimes met with. They may be the result of traumatism, when they generally contain blood, or they may be due to retention from obstruction of a duct, or from pressure on the main duct by a gall-stone. They may attain a large size, and cause symptoms by pressing on the stomach, Diaphragm, or common bile-duct. They generally push their way forwards between the stomach and transverse colon, and may then be felt as a definite tumour in the middle line of the upper part of the abdomen. The tumour is fixed and does not move with respiration. The treatment consists in opening the abdomen in the middle line, incising the cyst, evacuating its contents, and fixing its walls to the deeper layers of the abdominal wall. Drainage in the left loin, just below the last rib, can sometimes be established. When they are situated in the tail of the pancreas they have been removed. The pancreas is often the seat of cancer; this usually affects the head, and therefore speedily involves the bile-duct, leading to persistent jaundice; or it may press upon the portal vein, causing ascites, or involve the stomach, causing pyloric obstruction. The descending part of the duodenum is occasionally encircled by the head of the pancreas, and should the latter then be the seat of malignant disease or chronic inflammation it may cause obstruction of the duodenum. It has been said that the pancreas is the only abdominal viscus which has never been found in a hernial protrusion; but even this organ has been found in company with other viscera, in rare cases of diaphragmatic hernia.

The Liver (Hepar)

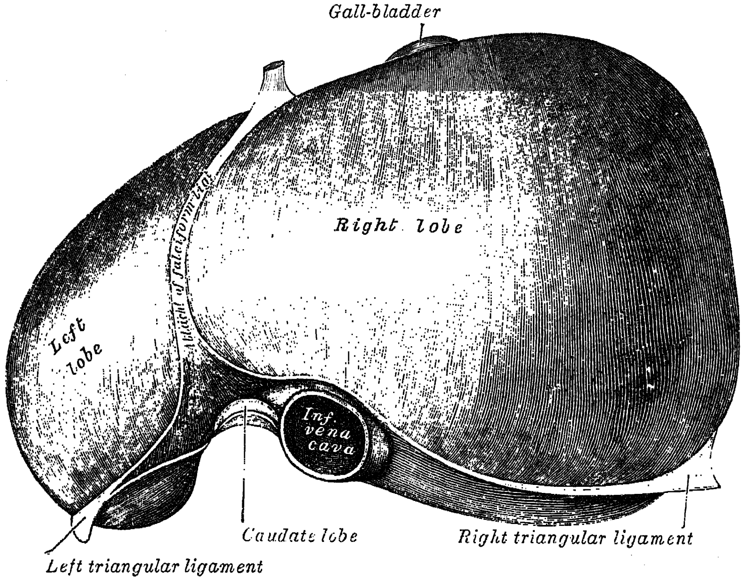
The **liver**, the largest gland in the body, is situated in the upper and right parts of the abdominal cavity, occupying almost the whole of the right hypochondrium, the greater part of the epigastrium, and not uncommonly extending into the left hypochondrium as far as the mammary line. In the male it weighs from 1·4 to 1·6 kilogm., in the female from 1·2 to 1·4 kilogm. It is relatively much larger in the fœtus than in the adult, constituting, in the former, about one-eighteenth, and in the latter, about one-thirty-sixth of the entire body weight. Its greatest transverse measurement is from 15 cm. to 20 cm. Vertically, near its right surface, it measures from 15 cm. to 17 cm., while its greatest anteroposterior diameter is on a level with the upper end of the right kidney, and is from 12 cm. to 15 cm.; opposite the vertebral column this diameter is reduced to about 7 cm. Its consistence is that of a soft solid; it is, however, friable and easily lacerated; its colour is a dark reddish-brown, and its specific gravity is 1·05.

When the liver has been hardened *in situ* it presents the appearance of a wedge, the base of which is directed to the right and the edge to the left. Symington describes its shape as that 'of a right-angled triangular prism with the right angles rounded off.'

The liver possesses five surfaces, viz. superior, inferior, anterior, posterior, and right. The superior, anterior, and right surfaces are united by round borders, but a sharp margin separates these surfaces from the inferior surface. A sickle-shaped fold of peritoneum, named the falciform ligament, is attached by its convex edge to the Diaphragm and the anterior abdominal wall, and by its concave edge to the anterior and superior surfaces of the liver, where it forms the boundary between the large right, and the small left, lobe of the liver (fig. 1139). In the free edge of this ligament there is a round cord, the *ligamentum teres hepatis*, which consists of the obliterated left umbilical vein.

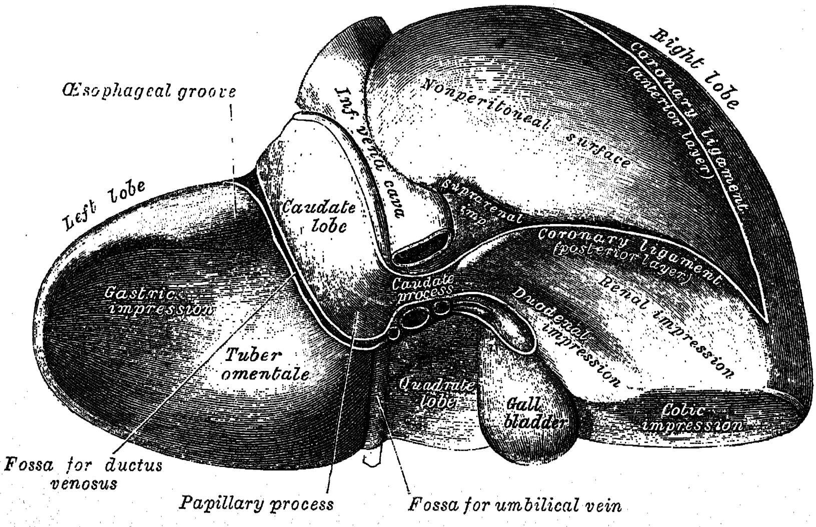
Fossæ.—The inferior and posterior surfaces of the liver (figs. 1140, 1141) are traversed by five fossæ or fissures, arranged somewhat like the letter H.

FIG. 1139.—The superior, anterior, and right lateral surfaces of the liver. (From a model by His.)



The left limb of the H is formed by the *left sagittal fossa*, which here separates the right from the left lobe; it consists of an anterior part, the fossa for the umbilical vein, and a posterior part, the fossa for the ductus venosus. The right limb of the H is formed by the *right sagittal fossæ*, the anterior of which

FIG. 1140.—The posterior and inferior surfaces of the liver. (From a model by His.)

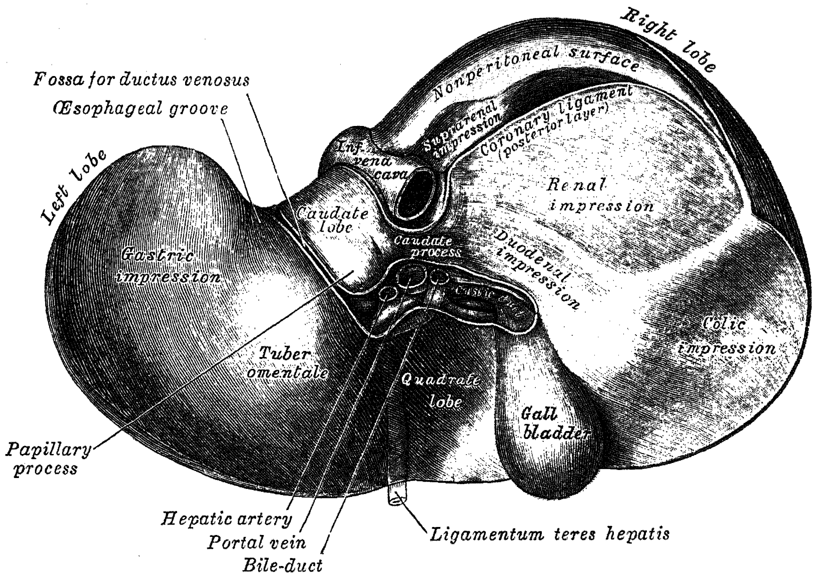


is the fossa for the gall-bladder, the posterior, the fossa for the inferior vena cava. The cross-bar of the H is represented by the porta hepatis.

The *fossa for the umbilical vein* (fig. 1140) is a deep cleft which runs backwards from a notch (*incisura umbilicalis*) on the anterior margin of the liver to the left end of the porta hepatis, where it joins the fossa for the ductus venosus. It forms the left boundary of a four-sided area named the quadrate lobe, and a part of the fossa is often bridged by a band of liver-substance, named the *pons hepatis*. In the fœtus it lodges the left umbilical vein, and in the adult, the obliterated remains of this vein, viz. the ligamentum teres hepatis.

The *fossa for the ductus venosus* (fig. 1140) is a deep cleft on the posterior surface of the liver, separating the left lobe from an oblong area, named the caudate lobe. In the fœtus it lodges the ductus venosus, and in the adult, a part of the lesser omentum, and a slender cord, named the *ligamentum venosum*, which represents the obliterated remains of the ductus venosus. The ligamentum venosum runs upwards and towards the right, in front of the upper end of the caudate lobe, and is attached to the wall of the inferior vena cava.

FIG. 1141.—The inferior surface of the liver. (From a model by His.)



The *fossa for the gall-bladder* (fig. 1141) is a shallow depression on the inferior surface of the right lobe, parallel with, but on the right of, the fossa for the umbilical vein. It forms the right boundary of the quadrate lobe, and extends from the anterior margin of the liver, which is often notched by it, to the right extremity of the porta hepatis.

The *fossa for the inferior vena cava* (fig. 1140) is a deep depression, occasionally a complete tunnel, on the posterior surface of the liver, between the caudate lobe and what is known as the 'bare area' of the right lobe (p. 1184). It is separated from the porta hepatis by a narrow band of liver-substance, named the caudate process. If the inferior vena cava be slit open the orifices of the hepatic veins will be displayed.

The *porta hepatis* (transverse fissure) (fig. 1141) is a deep fissure about 5 cm. long. It runs transversely between the posterior ends of the fossæ for the gall-bladder and umbilical vein, and separates the quadrate from the caudate lobe. Through the porta hepatis the portal vein, the hepatic artery and a plexus of nerves enter, and the right and left hepatic ducts and some lymphatic vessels leave, the liver. Near the right end of the porta hepatis the right and left hepatic ducts unite, at an obtuse angle, to form the hepatic duct. The hepatic duct and artery are placed in front of the portal vein, the duct lying on the right side of the artery. The lesser omentum is attached to the margins of the porta hepatis.

Lobes.—As already stated, the falciform ligament and the left sagittal fossa serve to divide the liver into a right and a left lobe.

The *left lobe* is thin, flattened from above downwards, and only about one-sixth of the size of the right. It presents superior, inferior and posterior surfaces which are described with the surfaces of the liver.

The *right lobe* is of a somewhat quadrilateral form. The porta hepatis and the fossæ for the gall-bladder and inferior vena cava traverse its posterior and inferior surfaces and divide its left portion into two smaller lobes, named the quadrate and caudate.

The *quadrate lobe* (figs. 1141, 1142) is situated on the inferior surface of the liver. It is bounded in front by the anterior margin, behind by the porta hepatis, on the right by the fossa for the gall-bladder, and on the left by the fossa for the umbilical vein. It is oblong in shape, its anteroposterior diameter being greater than its transverse.

The *caudate lobe* (Spigelian lobe) (fig. 1141) is situated on the posterior surface of the liver, opposite the lower three thoracic vertebræ. It is bounded above by the upper part of the ligamentum venosum, below by the porta hepatis, on the right by the fossa for the inferior vena cava, and on the left by the fossa for the ductus venosus. It has two free surfaces ; one, quadrilateral in shape, directed backwards and a little towards the left, is separated from the Diaphragm by the superior recess of the omental bursa (p. 1140), the other, directed forwards, and towards the left, forms the right wall of the fossa for the ductus venosus, and is in contact with the part of the lesser omentum which lies in this fossa. A notch divides the projecting lower end of the lobe into a round left part, named the *papillary process*, and a narrow right part, termed the *caudate process*. The latter separates the porta hepatis from the fossa for the inferior vena cava, and connects the caudate lobe with the inferior surface of the main part of the right lobe (fig. 1141).

Surfaces.—The *superior surface* of the liver (fig. 1139) includes portions of the right and left lobes. It fits under the vault of the Diaphragm, and is covered by peritoneum, with the exception of a small triangular area between the diverging layers of the falciform ligament. Its right and left portions are convex, but on its central part there is a shallow *cardiac impression* which corresponds with the position of the heart on the upper surface of the Diaphragm.

The *anterior surface*, triangular in shape, also comprises portions of the right and left lobes, and is covered by peritoneum except at the line of attachment of the falciform ligament. A large part of this surface is in contact with the Diaphragm, which separates it on the right side from the sixth to the tenth ribs and their cartilages, and on the left side from the seventh and eighth costal cartilages. Its central part lies behind the xiphoid process of the sternum and, in the angle between the diverging right and left costal cartilages, the anterior abdominal wall.

The *right surface* is convex from before backwards, and slightly so from above downwards. It is covered by peritoneum and lies against the right portion of the Diaphragm which separates it from the lower parts of the right lung and pleura ; outside these are the right costal arches from the seventh to the eleventh inclusive.

The *posterior surface* (fig. 1140) includes portions of the right and left lobes, and is thick and convex on the right, but thin on the left. Its central part is deeply concave in adaptation to the convexity formed by the vertebral column and the crura of the Diaphragm. A large part of this surface of the right lobe is not covered by peritoneum but is attached to the Diaphragm by areolar tissue. This non-peritoneal surface, or '*bare area*' as it is termed, is triangular in shape, and is limited above and below by the superior and inferior layers of the coronary ligament. Its base is formed by the fossa for the inferior vena cava, while its apex, directed downwards and lateralwards, corresponds with the meeting-point of the two layers of the coronary ligament. Immediately to the right of the lower part of the fossa for the inferior vena cava is a small triangular pit, the greater part of which is on the bare surface ; it lodges the right suprarenal gland and is named the *suprarenal impression*. Between the fossa for the inferior vena cava and that for the ductus venosus is the caudate lobe, already described. Immediately to the left of the fossa for the ductus venosus,

on the posterior surface of the left lobe, is the *œsophageal impression* in which the antrum cardiacum of the œsophagus is lodged.

The *inferior or visceral surface* (fig. 1141) is concave but uneven. It is directed downwards, backwards and towards the left, and is in contact with the stomach, duodenum, lesser omentum, right colic flexure, right kidney and right suprarenal gland. It is invested by peritoneum, except at the fossa for the gall-bladder and at the porta hepatis. On the inferior surface of the left lobe, and in direct continuity with the œsophageal groove, is the *gastric impression* which is moulded over the stomach. On the right of this impression is a rounded eminence, the *tuber omentale*, which fits into the concavity of the lesser curvature of the stomach, and is in contact with the lesser omentum. On the right of the fossa for the umbilical vein is the quadrate lobe which is concave and lies over the pyloric part of the stomach and the beginning of the duodenum, when these are dilated. When, on the other hand, the stomach is empty the quadrate lobe is in contact with the superior part of the duodenum and a portion of the transverse colon. Behind the quadrate lobe are the porta hepatis and the papillary and caudate processes, already described. There are three impressions, colic, renal and duodenal, on that part of the right lobe which is placed on the right side of the fossa for the gall-bladder. The *colic impression*, produced by the right colic flexure, is shallow and is situated anteriorly. The *renal impression*, posterior to and deeper than the colic impression, is occupied by the upper part of the right kidney, and frequently extends for a short distance on to the lower part of the 'bare area.' The *duodenal impression* is between the renal impression and the neck of the gall-bladder. It is a narrow, concave surface which comes into contact with the descending part of the duodenum.

The *anterior margin* of the liver is sharp, and marked, at the attachment of the falciform ligament, by the incisura umbilicalis (p. 1183), and frequently by a second notch at the fundus of the gall-bladder. In adult males this margin generally corresponds with the lower edge of the thorax in the right mammary line, but in women and children it usually projects below the ribs.

Ligaments.—The liver is connected to neighbouring structures by ligaments. These, except the ligamentum teres hepatis and the ligamentum venosum, consist of folds or reflections of the peritoneum and comprise the falciform, the coronary, the right and left triangular, the hepatogastric and the hepatoduodenal ligaments.

The *falciform ligament* connects the liver to the Diaphragm and the anterior abdominal wall, and is a sickle-shaped fold consisting of two layers of peritoneum closely united together. Its convex margin is fixed to the inferior surface of the Diaphragm, and to the posterior surface of the anterior abdominal wall about 3 or 4 cm. to the right of the median plane, and extending downwards as far as the umbilicus. Its concave margin is attached to the anterior and superior surfaces of the liver and to the fossa for the umbilical vein on its inferior surface. In its base or free edge are contained the ligamentum teres hepatis and the small para-umbilical veins (p. 744). At the posterior part of the superior surface of the liver the two layers of the falciform ligament separate from one another and expose a small triangular area which is uncovered by peritoneum. The right layer of the ligament is continuous with the superior layer of the coronary ligament, the left with the anterior layer of the left triangular ligament (fig. 1139).

The *coronary ligament* (fig. 1140) is formed by the reflections of the peritoneum from the liver to the Diaphragm at the upper and lower boundaries of the 'bare area,' and consists of a superior layer which is continuous with the right layer of the falciform ligament, and an inferior layer which passes to the right kidney and suprarenal gland and is termed the *hepatorenal ligament*.

The *right triangular ligament* (right lateral ligament) (fig. 1139) is situated at the right extremity of the 'bare area,' and is a small fold which passes to the Diaphragm. It is formed by the apposition of the two layers of the coronary ligament.

The *left triangular ligament* (left lateral ligament) (fig. 1139) is larger than the right. It connects the posterior part of the upper surface of the left lobe of the liver to the Diaphragm, and its anterior layer is continuous with the left layer of the falciform ligament.

The *hepatogastric* and *hepatoduodenal* ligaments together constitute the lesser omentum which is attached below to the lesser curvature of the stomach and the superior part of the duodenum, and above to the liver along the margins of the porta hepatis and at the bottom of the fossa for the ductus venosus. Between the layers of the hepatoduodenal ligament are contained the bile-duct, the portal vein and the hepatic artery, together with some lymph-glands and lymphatic vessels, and a plexus of nerves.

The *ligamentum teres hepatis* (fig. 1141) is a fibrous cord resulting from the obliteration of the left umbilical vein of the fœtus. It runs from the umbilicus upwards and backwards in the free margin of the falciform ligament to the incisura umbilicalis, and above this in the fossa for the umbilical vein to the porta hepatis where it joins the left branch of the portal vein. Before birth the left umbilical vein conveyed blood from the placenta to the fœtus.

The *ligamentum venosum* (*Arantii*) is a fibrous cord resulting from the obliteration of the ductus venosus. It ascends in the fossa for the ductus venosus and unites the left branch of the portal vein to the terminal part of the inferior vena cava. Before birth the ductus venosus transmitted to the inferior vena cava some of the blood conveyed from the placenta by the left umbilical vein.

Vessels and Nerves.—The vessels connected with the liver are the portal vein, and the hepatic artery and veins.

The *portal vein* and *hepatic artery*, accompanied by numerous nerves, ascend between the layers of the lesser omentum to the porta hepatis where each divides into two branches; the *bile-duct* and lymphatic vessels descend from the porta hepatis between the layers of the same omentum. They are all enveloped in a loose areolar tissue, the *fibrous capsule of Glisson*, which accompanies the vessels in their course through the portal canals in the interior of the liver (fig. 1146).

Fig. 1142.—A longitudinal section through a hepatic vein. (After Kiernan.)

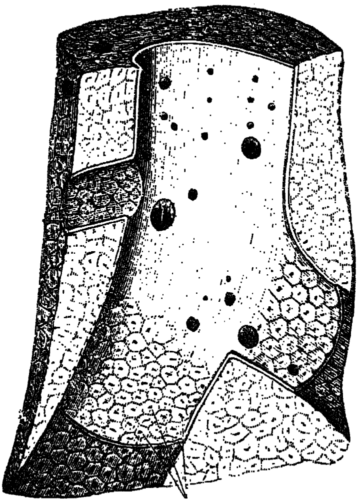
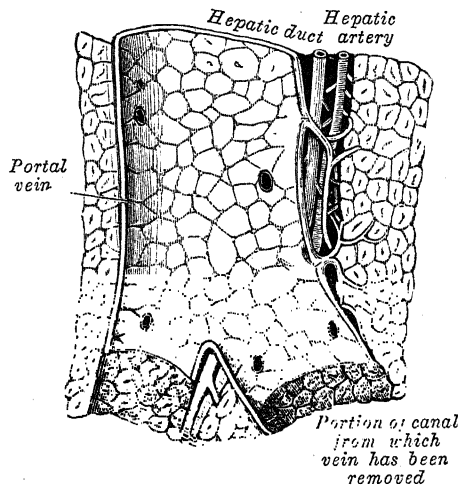


Fig. 1143.—A longitudinal section through a small portal vein and canal. (After Kiernan.)



The *hepatic veins* (fig. 1142) convey the blood from the liver to the inferior vena cava, and are described on p. 741. They have very little cellular investment, but what there is binds them closely to the walls of the canals through which they run; so that, on section of the liver, they remain widely open and are solitary, and may be easily distinguished from the branches of the portal vein, which are more or less collapsed, and always accompanied by an artery and duct.

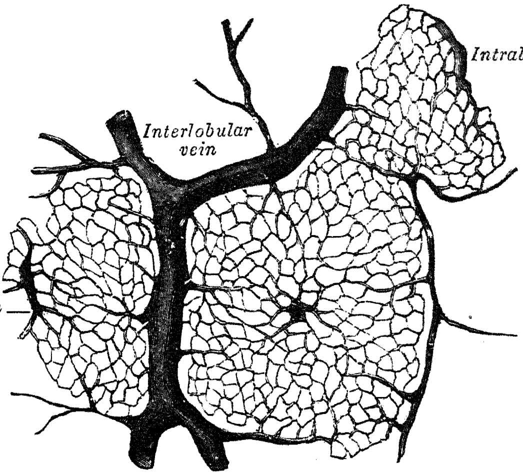
The *lymphatic vessels* of the liver are described on p. 771.

The *nerves* of the liver, derived from the left vagus and sympathetic, enter at the porta hepatis and accompany the vessels and ducts to the interlobular spaces. Here, according to Korolkow, the medullated fibres are distributed almost exclusively to the coats of the blood-vessels; while the non-medullated enter the lobulus and ramify between the cells.

Structure of the liver.—The greater part of the liver is covered with peritoneum, underneath which is a thin capsule of connective tissue. With the naked eye the liver can be

seen to consist of an enormous number of polyhedral lobules (fig. 1145), each of which is about 1 mm. in diameter. In the pig each lobule is sharply marked off from those adjoining it by connective tissue septa, but in the human liver there are no such definite boundaries.

FIG. 1144.—A section through the injected liver of a dog.

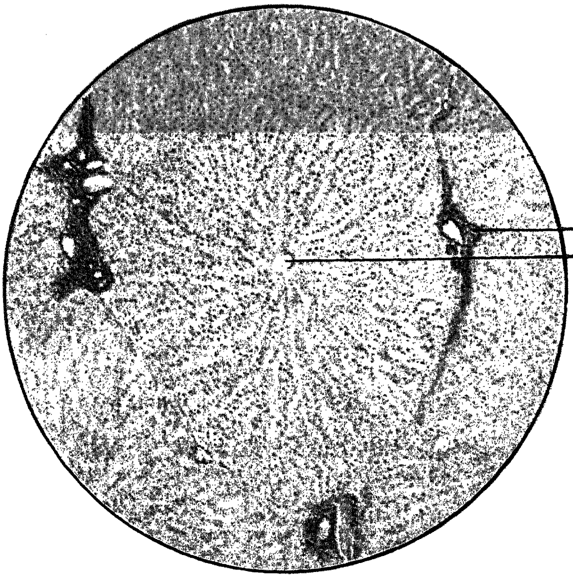


A *lobule* consists of a mass of cells, arranged in columns which radiate from a central vein (fig. 1145). Between the columns are irregular blood-vessels (sinusoids).

A *liver-cell* is approximately cubical in shape, and is from 12μ to 25μ in diameter. It possesses one or two spherical nuclei, and its protoplasm usually contains granules of glycogen, and of a compound of iron. Fat droplets may also be present in the liver-cell.

Blood is conveyed to the liver by the portal vein and hepatic artery. These vessels enter the liver at the porta hepatis, and, as already stated, are enclosed together with the

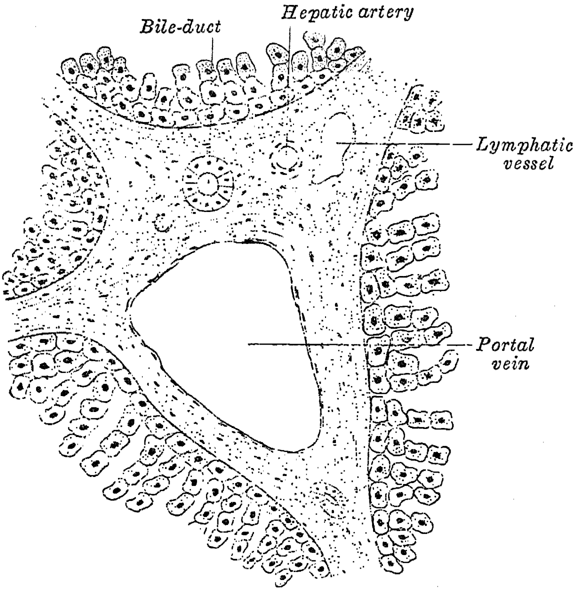
FIG. 1145.—A section through a lobule of the human liver. Stained with hæmatoxylin and eosin. ×60.



hepatic duct in a connective tissue sheath termed Glisson's capsule. In the porta hepatis the portal vein, hepatic artery and hepatic duct each divide into right and left branches, and these branches subsequently ramify, in their connective tissue capsule,

throughout the substance of the liver, and are accompanied by nerves and lymphatic vessels. The spaces occupied by these various structures are named *portal canals* (fig. 1146). The smallest branches of the portal vein form *interlobular plexuses* between the lobules, and from these plexuses capillary-like vessels, named sinusoids, run between the columns of liver-cells and open into the *intralobular* veins in the centres of the lobules. The intralobular veins join to form *sublobular veins*, and these unite to form the *hepatic veins* (fig. 1142) which drain the blood from the liver into the inferior vena cava.

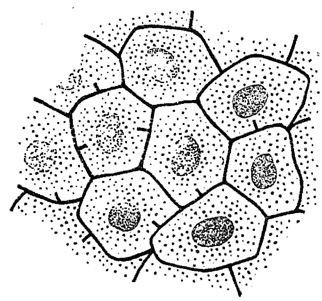
Fig. 1146.—A transverse section through a portal canal of a pig. × 250.



The *hepatic artery* conveys arterial blood to the connective tissue of the liver, to the walls of the subdivisions of the portal vein, and to the bile-ducts; its ultimate branches open into the interlobular plexuses and provide oxygenated blood for the liver cells.

The *sinusoids* are wider and more irregular than capillaries, and have an incomplete wall formed of branched cells (stellate cells of Kupffer). There is no lymph-space between the wall of the sinusoid and the liver-cells, and, in consequence of the gaps in the former, the blood comes into direct contact with the hepatic cells. Moreover, according to Herring and Simpson, minute channels penetrate the liver-cells, conveying the constituents of the blood into their substance.

Fig. 1147.—The bile-capillaries of a rabbit, shown by Golgi's method. × 450.



The *bile-ducts* do not penetrate the lobules, but receive minute canaliculi which convey the bile from the cells to the periphery of the lobules. These canaliculi, or *bile-capillaries*, are merely little channels or spaces between adjacent cells, and are always separated from the sinusoids by at least half the width of a liver-cell (fig. 1147).

Structure of the ducts.—The walls of the biliary ducts consist of a connective tissue coat, in which are non-striped muscle-cells arranged both circularly and longitudinally, and an epithelial layer, consisting of short columnar cells resting on a basement-membrane.

Nerve-fibrils are said to be distributed between the cells of the liver, and even to enter their substance.

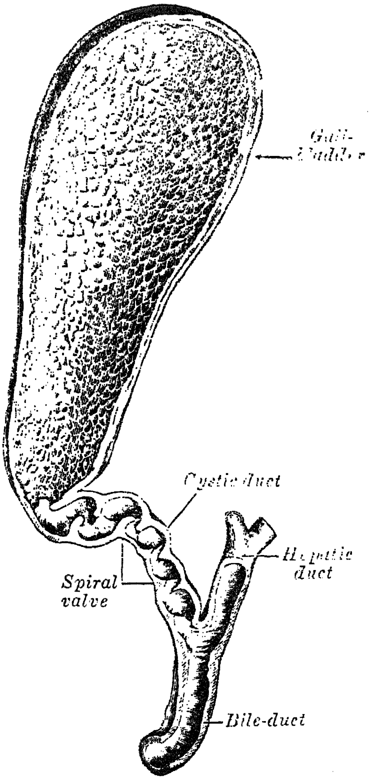
The Excretory Apparatus of the Liver

The excretory apparatus of the liver consists of (1) the *hepatic duct*, formed by the junction of the two main ducts, which leave the liver at the porta hepatis; (2) the *gall-bladder*, which serves as a reservoir for the bile; (3) the *cystic duct*, or duct of the gall-bladder; and (4) the *bile-duct*, formed by the junction of the hepatic and cystic ducts.

The hepatic duct.—Two main ducts (right and left hepatic) issue from the liver at the porta hepatis and unite to form the hepatic duct, which passes downwards for about 3 cm., and is joined at an acute angle by the cystic duct; by the union of the hepatic with the cystic duct the bile-duct is formed. The hepatic duct is on the right of the hepatic artery and in front of the portal vein.

The **gall-bladder** (vesica fellea) (figs. 1141, 1148) is a conical or pear-shaped sac, lodged in a fossa on the under surface of the right lobe, and extending from near the right extremity of the porta hepatis to the anterior border of the liver. Its upper surface is attached to the liver by connective tissue; its under surface and sides are covered with peritoneum continued from the surface of the liver. Occasionally it is completely invested with peritoneum and may be connected to the liver by a short mesentery. It is from 7 cm. to 10 cm. long, 3 cm. broad at its widest part, and holds from 30 c.cm. to 50 c.cm. It is divided into a fundus, body, and neck.

FIG. 1148.—The gall-bladder and bile-ducts laid open. (Spalteholz.)



The *fundus*, or expanded end, is directed downwards, forwards and to the right. It projects beyond the anterior margin of the liver, and comes into relationship with the posterior surface of the anterior abdominal wall below the ninth right costal cartilage, and behind the point where the lateral edge of the right Rectus abdominis touches the lower margin of the thoracic wall; posteriorly the fundus is in relation with the transverse colon. The *body* is directed upwards, backwards and to the left; near the right end of the porta hepatis it is continuous with the neck. It is in relation, by its upper surface, with the liver; by its under surface, with the commencement of the transverse colon; and farther back usually with the upper end of the descending portion of the duodenum, but sometimes with the superior portion of the duodenum or pyloric end of the stomach. The *neck* is narrow; it curves upwards and forwards, and then, turning abruptly backwards and downwards, becomes continuous with the cystic duct; at its point of continuity with the cystic duct there is a constriction. The neck is attached to the liver by areolar tissue in which the cystic artery is imbedded. The mucous membrane which lines the neck projects into its lumen in the form of oblique ridges, forming a sort of spiral valve.

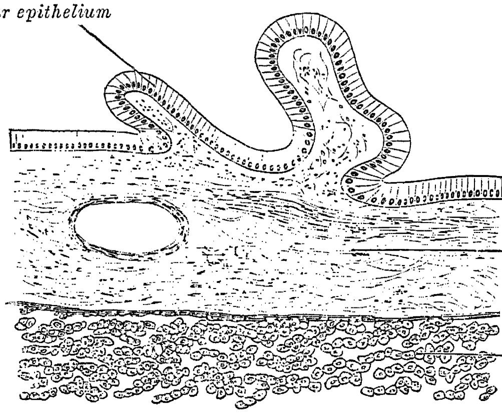
The **cystic duct**, from 3 cm. to 4 cm. long, passes backwards, downwards, and to the left from the neck of the gall-bladder, and joins the hepatic duct to form the bile-duct; it runs parallel with and adheres to the hepatic duct for a short distance before joining with it. The mucous membrane lining its interior is thrown into a series of crescentic folds, from five to twelve in number, similar to those found in the neck of the gall-bladder. They project into the duct in regular succession, and are directed obliquely round the tube, presenting much the appearance of a crescentic spiral valve. When the duct is distended, the spaces between the folds are dilated, and the exterior of the duct appears twisted.

The **bile-duct** (common bile-duct, ductus choledochus) is formed by the junction of the cystic and hepatic ducts; it is about 7 cm. long, and of the diameter of a goose-quill.

It runs at first downwards, backwards, and to the left in the right border of the lesser omentum, in front of the portal vein, and on the right of the hepatic artery. It passes behind the superior portion of the duodenum, and then runs in a groove, on the posterior surface of the head of the pancreas; here it is situated in front of the inferior vena cava, and is sometimes completely imbedded in the pancreatic substance. Its terminal part lies for a short distance along the right side of the terminal part of the pancreatic duct and

passes with it obliquely through the coats of the duodenum. The two ducts unite and open by a common orifice upon the summit of a papilla (*papilla duodeni*), situated at the medial side of the descending portion of the duodenum, 7 cm. to 10 cm. from the pylorus (fig. 1137). The short tube formed by the union of the two ducts is dilated into an ampulla, the *ampulla of Vater*.

FIG. 1149.—A transverse section through the wall of the gall-bladder.



Structure (fig. 1149).—The gall-bladder has three coats: serous, fibromuscular, and mucous.

The *external or serous coat* is derived from the peritoneum; it completely invests the fundus, but covers only the under surfaces and sides of the body and neck.

The *fibromuscular coat*, a thin but strong layer, consists of dense fibrous tissue, mixed with plain muscular fibres, which are disposed chiefly in a longitudinal direction, a few running transversely.

The *internal or mucous coat* is loosely connected with the fibrous layer. It is generally of a yellowish-brown colour, and is elevated into minute rugæ. It is continuous through the hepatic duct with that of the ducts of the liver, and through the bile-duct with that of the duodenum. Its epithelium is columnar, and secretes mucin, or, in some animals, a nucleoprotein.

The coats of the large biliary ducts are an external or fibrous, and an internal or mucous. The fibrous coat is composed of strong fibro-areolar tissue, with a certain amount of muscular tissue, arranged, for the most part, in a circular manner around the ducts. The mucous coat is continuous with the lining membrane of the hepatic ducts and gall-bladder, and also with that of the duodenum; and, like the mucous membrane of these structures, its epithelium is of the columnar variety. It is provided with numerous mucous glands, which are lobulated and open by minute orifices scattered irregularly in the larger ducts.

Applied Anatomy.—On account of its large size, its fixed position, and its friability, the liver is more frequently ruptured than any of the other abdominal viscera. The rupture may vary from a slight scratch to an extensive and complete laceration of its substance, dividing it into two parts. Sometimes an internal rupture, without laceration of the peritoneal covering, takes place, and such injuries are most susceptible of repair; but small tears of the surface may also heal; when, however, the laceration is extensive, death usually takes place from hæmorrhage, on account of the fact that the hepatic veins are contained in rigid canals in the liver-substance and are unable to contract, and are moreover unprovided with valves. The liver may also be torn by the end of a broken rib perforating the Diaphragm. It may be injured by stabs or other punctured wounds, and when these are inflicted through the chest-wall, the pleural and peritoneal cavities may both be opened up, and both lung and liver wounded. In cases of laceration of the liver, when there is evidence that bleeding is going on, the abdomen must be opened, the laceration sought for, and the bleeding arrested. This may be done temporarily by introducing the forefinger into the epiploic foramen and placing the thumb on the lesser omentum, and compressing the hepatic artery and portal vein between the two. The margins of the laceration, if small, can be brought together and sutured by means of a blunt curved needle passed from one side of the wound to the other; this must be done with the greatest gentleness, as the liver substance is very friable. When the laceration is extensive it must be packed with gauze, the end of which is allowed to hang out of the external wound.

Abscess of the liver is of not infrequent occurrence. The so-called *tropical abscess* is due to absorption, from the intestine, of the amœba of dysentery, which reaches the liver through the portal system and causes the formation of a large chronic abscess; this may enlarge in many different directions on account of the relations of the liver to other organs. Thus it has been known to burst into the lungs, when the pus is coughed up; or into the stomach, when the pus is vomited; it may burst into the colon, or duodenum; or, by perforating the Diaphragm, it may empty itself into the pleural cavity. It often makes its way forwards, and points on the anterior abdominal wall, and finally it may burst into the peritoneal or pericardial cavities. Abscesses of the liver frequently require opening, and this must be done by an incision in the abdominal wall, in the thoracic wall, or in the lumbar region, according to the direction in which the abscess is tracking. The incision through the abdominal wall is to be preferred when possible. The abdominal wall is incised over the swelling, and, unless the peritoneum is adherent, gauze is packed all round the exposed liver surface, the abscess opened, and a large drainage tube inserted.

Hydatid cysts are more often found in the liver than in any of the other viscera. The reason of this is not far to seek. The embryo of the egg of the Tænia echinococcus, being liberated in the stomach by the disintegration of its shell, bores its way through the gastric walls and usually enters a blood-vessel, and is carried by the blood-stream to the hepatic capillaries, where its onward course is arrested, and where it undergoes development into the fully formed hydatid.

Ptosis of the liver, or hepatoptosis, from abnormal laxity of its ligaments and failure of the support it usually receives from the subjacent viscera, is an occasional cause of various nervous and gastro-intestinal disturbances. It has been very fully described by Glénard and his pupils. In women who have used very tight corsets and in men who have worn tightly buckled belts, the lower margin of the right lobe may become elongated by the pressure, producing an abnormal lobe known as the *linguiform* or *Riedel's* lobe. This may cause indefinite abdominal symptoms suggesting dyspepsia or disease of the gall-bladder; and if discovered accidentally, a Riedel's lobe may be mistaken for a tumour of the right kidney, of the colon or pancreas, or even of the vermiform process.

The gall-bladder may become distended in cases of obstruction of the cystic duct or of the bile-duct, or from a collection of gall-stones in its interior, thus forming a large tumour. The swelling is pear-shaped, and projects downwards and forwards towards the umbilicus. It moves with respiration, since it is attached to the liver. To relieve this condition, the gall-bladder must be opened (*cholecystotomy*) and the gall-stones removed. The operation is performed by an incision, 5 cm. to 7 cm. long, through the lateral part of the right Rectus, commencing at the costal margin. The peritoneal cavity is opened, and the tumour having been found, gauze is packed round it to protect the peritoneal cavity, and it is aspirated. When the contained fluid has been evacuated the flaccid bladder is drawn out of the abdominal wound and its wall incised; any gall-stones in the bladder are now removed. If the case is one of obstruction of the duct, an attempt must be made to dislodge the stone by manipulation through the wall of the duct. If this does not succeed, the safest plan is to incise the duct, extract the stone, and close the incision by fine sutures in two layers. The obstruction having been removed, the edges of the incision in the gall-bladder may be sutured round a drainage tube which is inserted into the cavity; this fistulous opening usually closes in the course of a few weeks. The gall-bladder may be completely removed if it be quite certain that no cause for biliary obstruction remains: this is also done for primary malignant growth of the viscus.

Obstruction of the bile-duct apart from stone is often due to occlusion of this canal by pressure of malignant growths, especially those commencing in the pylorus or pancreas. It is also seen following ulceration of the duct, cicatricial contraction of the scar tissue taking place. Enormous distension, both of the bile-duct itself and of its radicles in the liver substance, may occur at times.

THE UROGENITAL APPARATUS

The urogenital apparatus consists of (*a*) the urinary organs for the secretion and discharge of the urine, and (*b*) the genital organs, which are concerned with the process of reproduction.

THE URINARY ORGANS

The urinary organs comprise the *kidneys*, which secrete the urine; the *ureters*, which convey it to the *urinary bladder*; and the *urethra*, through which it is discharged from the urinary bladder.

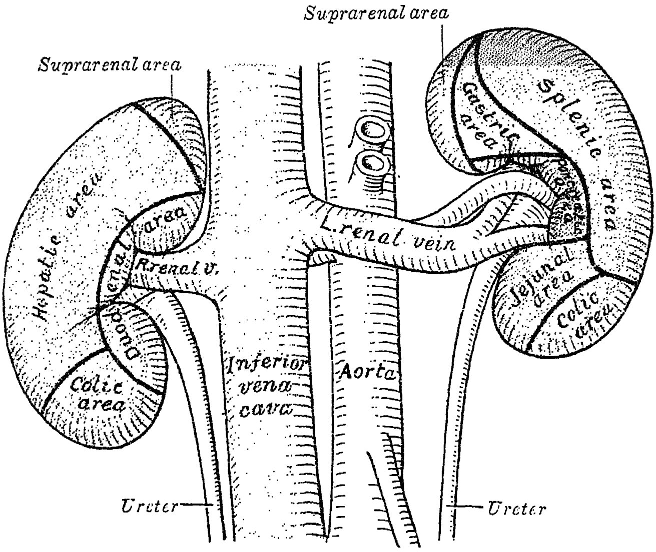
The Kidneys (Renes)

The **kidneys** are situated in the posterior part of the abdomen, one on either side of the vertebral column, behind the peritoneum; they are surrounded by a mass of fat and some loose areolar tissue. Their upper ends are on a level with the upper border of the twelfth thoracic vertebra, their lower, with the third lumbar vertebra. The right kidney is usually slightly lower than the left, probably on account of the vicinity of the liver; the left is a little longer and narrower than the right. The long axis of each kidney is directed downwards and lateralwards; the transverse axis lateralwards and backwards.

Each kidney is about 11 cm. in length, 6 cm. in breadth, and about 3 cm. in thickness. In the adult male the weight of the kidney varies from 125 gm. to 170 gm.; in the adult female from 115 gm. to 155 gm.

The kidney has a characteristic form, and presents for examination two surfaces, two borders, and an upper and a lower end.

Fig. 1150.—The anterior surfaces of the kidneys, showing the areas of contact of the neighbouring viscera.



Relations.—The *anterior surface* (figs. 1135, 1150) of either kidney is convex, and looks forwards and lateralwards. Its relations to adjacent viscera differ on the two sides of the body.

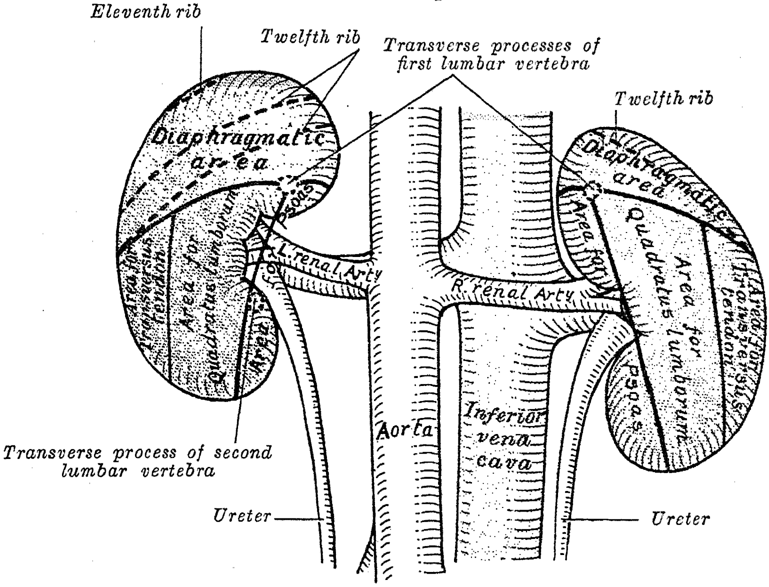
(*a*) *Anterior surface of right kidney*.—A narrow portion at the upper extremity is in contact with the right suprarenal gland. A large area just below this and involving about three-fourths of the surface, lies in the renal impression on the inferior surface of the liver, and a narrow but somewhat variable area near the medial border is in contact with the descending part of the duodenum. The lower part of the anterior surface is in contact laterally with the right colic flexure, and medially, as a rule, with the small intestine. The area in relation with the small intestine and almost the whole of the area in contact with the liver are covered by peritoneum; the suprarenal, duodenal, and colic areas are devoid of peritoneum.

(*b*) *Anterior surface of left kidney*.—A small area along the upper part of the medial border is in relation with the left suprarenal gland, and the upper two-thirds of the lateral half of the anterior surface are in contact with the renal impression on the spleen. A somewhat quadrilateral field, about the middle of the anterior surface, marks the site of contact with the body of the pancreas, on the deep surface of which are the lienal vessels. Above this is a small triangular portion, between the suprarenal and splenic areas, in

contact with the stomach. Below the pancreatic and splenic areas the lateral part is in relation with the left colic flexure, the medial with a small part of the jejunum. The area in contact with the stomach is covered by the peritoneum of the omental bursa, while those in relation to the spleen and the jejunum are covered by the peritoneum of the main cavity; behind the peritoneum of the jejunal area are some branches of the left colic vessels. The suprarenal, pancreatic, and colic areas are devoid of peritoneum.

The *posterior surface* (figs. 1151, 1153) of each kidney is directed backwards and medialwards. It is imbedded in areolar and fatty tissue, and is devoid of peritoneal covering. It lies upon the Diaphragm, the medial and lateral lumbocostal arches, the Psoas major, the Quadratus lumborum, and the tendon of origin of the Transversus abdominis, the subcostal vessels, and the last thoracic, iliohypogastric, and ilioinguinal nerves. The right kidney rests

FIG. 1151.—The posterior surfaces of the kidneys, showing the areas of relation to the parietes.



upon the twelfth rib, the left usually on the eleventh and twelfth. The Diaphragm separates the kidney from the pleura, which dips down to form the phrenicocostal sinus, but frequently the muscular fibres of the Diaphragm are defective or absent over a triangular area immediately above the lateral lumbocostal arch, and when this is so the perinephric areolar tissue is in contact with the diaphragmatic pleura.

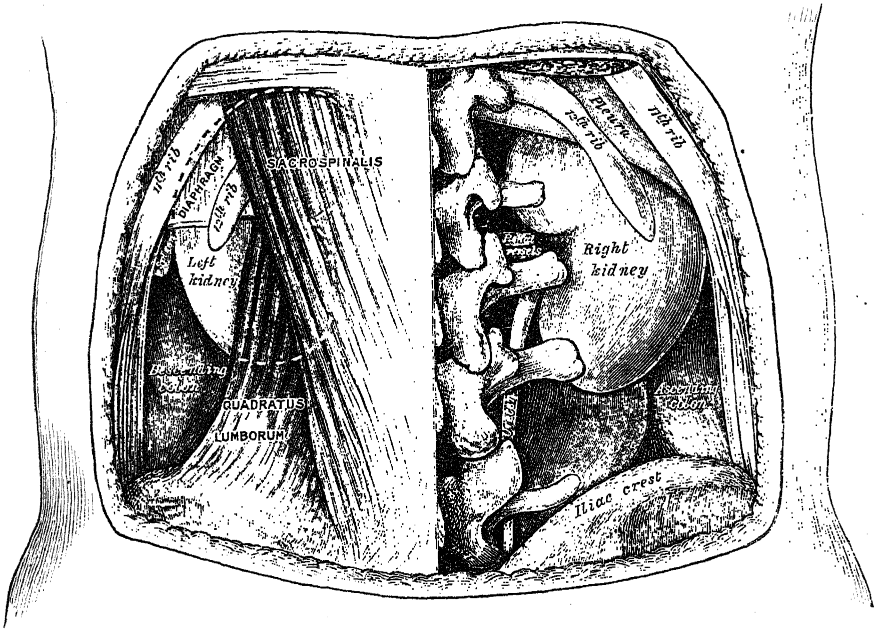
The *upper end* of the kidney is thick and round, and is nearer the median line than the lower; it is surmounted by the suprarenal gland, which covers also a small portion of the anterior surface. The *lower end*, smaller and thinner than the superior, extends to within 5 cm. of the iliac crest.

The *lateral border* is convex; that of the left kidney is in contact, at its upper part, with the spleen.

The *medial border* is concave in the centre and convex at either end; it is directed a little downwards and forwards. In its central part is a deep vertical fissure, the *hilum*, which is bounded by an anterior and a posterior lip, and transmits the renal vessels and nerves and the funnel-shaped upper end (*renal pelvis*) of the ureter. The relative positions of the main structures in the hilum are as follows: the renal vein is in front, the renal artery in the middle, and the renal pelvis behind. Frequently, however, branches both of artery and vein are situated behind the renal pelvis. Above the hilum the medial border is in relation with the suprarenal gland, below with the commencement of the ureter.

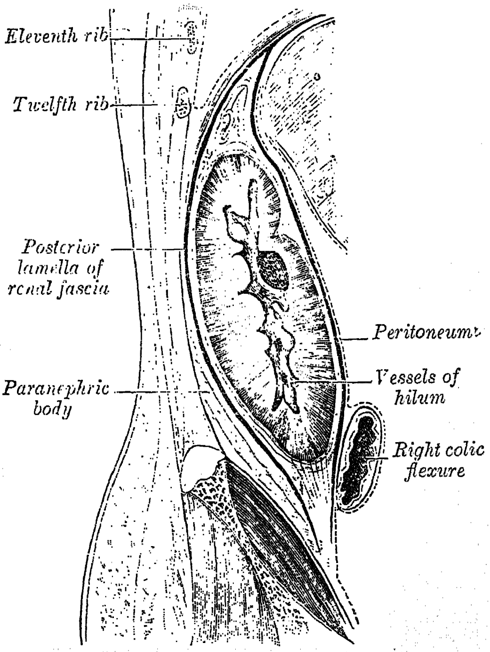
The hilum leads into a central recess or cavity named the *renal sinus*, which is lined by a continuation of the capsule of the kidney and is almost

Fig. 1152.—The relations of the kidneys from behind.



entirely filled by the renal pelvis and renal vessels; on the wall of the sinus are numerous nipple-like elevations, the *renal papillæ*. Within the sinus the renal pelvis divides into two, sometimes three, large branches which are termed the *calyces renales majores*, and each of these divides again into several short branches named the *calyces renales minores* (fig. 1156). In all, there are usually from seven to thirteen of these minor calyces; each expands as it approaches the wall of the renal sinus, and the expanded end is indented and moulded round from one to three renal papillæ. The wall of the expanded end of the calyx is firmly adherent to the capsule lining the renal sinus; it is perforated by the collecting tubes which open on the summits of the renal papillæ.

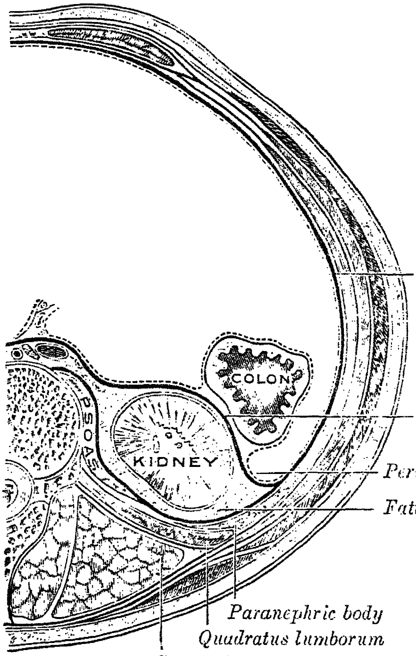
Fig. 1153.—A sagittal section through the posterior abdominal wall showing the relations of the capsule of the kidney. (After Gerota.)



The kidney and its vessels are imbedded in a mass of fatty tissue, termed the *fatty capsule*, which is thickest at the borders of the kidney and is prolonged through the hilum into the renal sinus. The kidney and the fatty capsule are enclosed in a sheath of

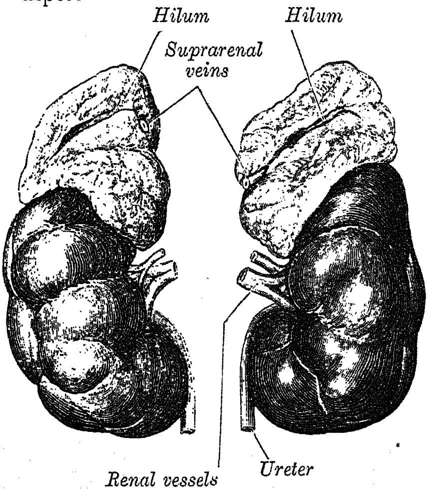
fibrous tissue continuous with the subperitoneal fascia, and named the *renal fascia* (figs. 1153, 1154). At the lateral border of the kidney the renal fascia splits into an anterior and a posterior layer. The anterior layer is carried medialwards in front of the kidney and its vessels, and is continuous over the aorta with the corresponding layer of the opposite side. The posterior layer extends medialwards behind the kidney and blends with the fascia on the Quadratus lumborum and Psoas major, and through this fascia is attached to the vertebral column. Above the suprarenal gland the two layers of the renal fascia fuse, and unite with the fascia of the Diaphragm; below the kidney they remain separate, and are gradually lost in the subperitoneal fascia of the iliac fossa. The renal fascia is connected to the fibrous tunic of the kidney by numerous trabeculæ, which traverse the fatty capsule, and are strongest near the lower end of the organ. Behind the renal fascia is a considerable quantity of fat, which constitutes the *paranephric body*. The kidney is held in position partly through the attachments of the renal fascia and partly by the apposition of the neighbouring viscera.

Fig. 1154.—A transverse section, showing the relations of the capsule of the kidney. (After Gerota.)



In the fœtus the kidney consists of about twelve distinct lobules (fig. 1155), but in the adult these are fused and the kidney presents a uniformly smooth surface.

Fig. 1155.—The kidneys and suprarenal glands of a new-born child. Anterior aspect.



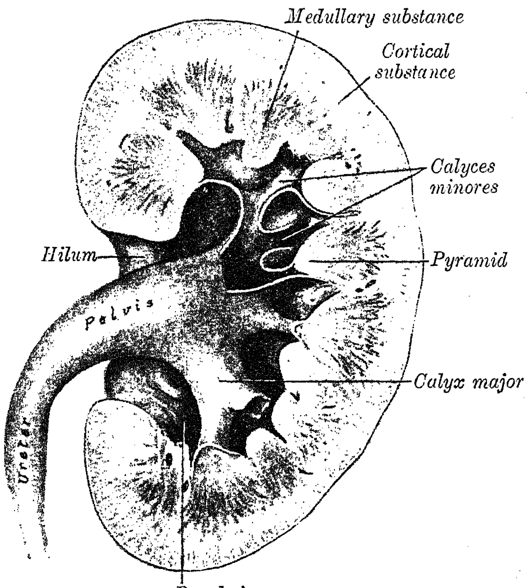
General structure of the Kidney.—The kidney is invested by a fibrous capsule which is easily stripped off; beneath the fibrous capsule is an incomplete layer of smooth muscular fibres. If a vertical section be made from its lateral to its medial border, and the loose tissue and fat removed from around the vessels and the excretory duct, the *renal sinus* will be seen surrounded at all parts but one by the proper kidney-substance (fig. 1156). The fibrous capsule is prolonged into the sinus round the lips of the hilum, to become continuous with the outer coat of the renal pelvis.

The kidney is composed of an internal medullary and an external cortical substance.

The *medullary substance* consists of a series of pale striated conical masses, termed the *renal pyramids*, the bases of which are directed towards the circumference of the kidney, while their apices converge towards the renal sinus, where they form prominent papillæ projecting into the interior of the calyces, each calyx minor receiving from one to three papillæ.

The *cortical substance* is reddish-brown in colour, and soft and granular in consistence. It lies immediately beneath the fibrous tunic, arches over the bases of the pyramids, and dips in between adjacent pyramids towards the renal sinus. The parts dipping in between the pyramids are named the *renal columns* (Bertini), while the portions which connect the renal columns with each other and intervene between the bases of the pyramids and the fibrous tunic are called the *cortical arches*. If the cortex be examined with a lens, it will be seen to consist of a series of lighter-coloured, conical areas, termed *medullary rays*, and a darker-coloured intervening substance, which from the complexity of its structure is named the *convoluted part*. The rays gradually taper towards the circumference of the kidney, and consist of a series of outward prolongations from the base of each renal pyramid.

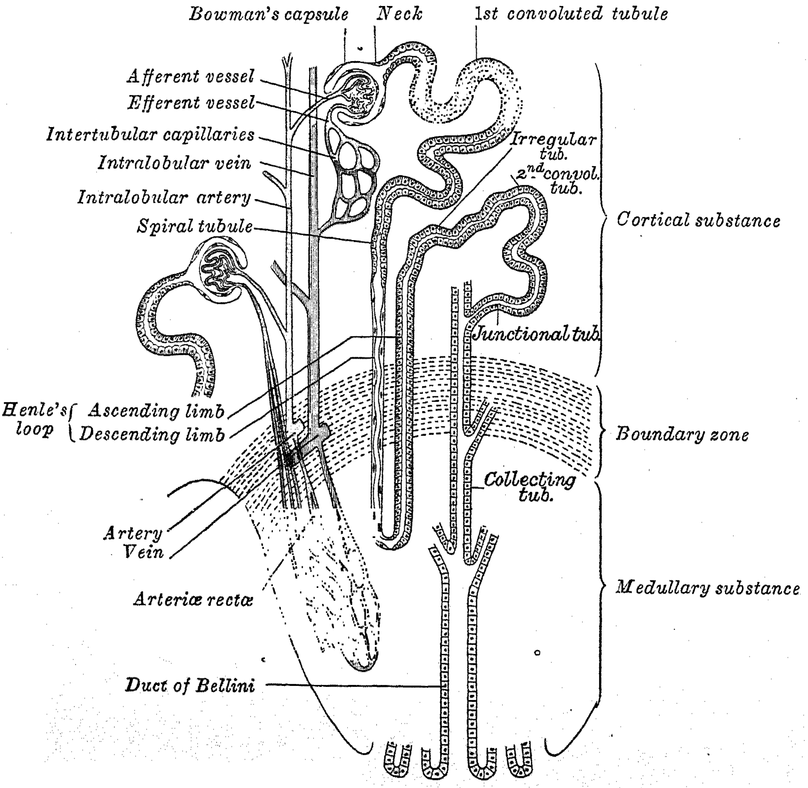
Fig. 1156.—A vertical section through a kidney.



The cortical and medullary substances are made up of renal tubules and blood-vessels, united and bound together by a connecting stroma.

Minute Anatomy.—The *renal tubules* (fig. 1157) commence in the cortical substance, and after pursuing a very tortuous route through the cortical and medullary substances finally end at the apices of the renal pyramids by open mouths. If

Fig. 1157.—A scheme of a renal tubule and its vascular supply.



the surface of one of the papillæ be examined with a lens, it will be seen to be studded over with minute openings, the orifices of the renal tubules, from sixteen to twenty in number, and if pressure be made on a fresh kidney, urine will be seen to exude from these orifices. The tubules commence in the convoluted part and renal columns as the *Malpighian bodies*, which are small rounded masses of a deep red colour, averaging about

Fig. 1158.—The distribution of the blood-vessels in the cortex of kidney.

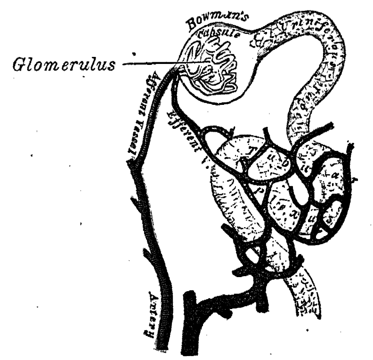
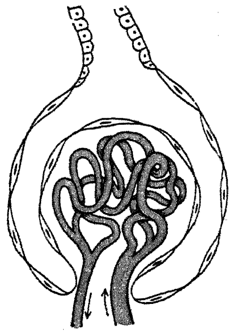


Fig. 1159.—A glomerulus.



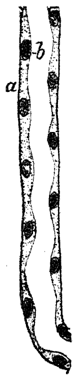
0·2 mm. in diameter. Each of these bodies is composed of two parts: a central *glomerulus* of vessels, and a membranous envelope, the *capsule of Bowman*, which is the small pouch-like commencement of a renal tubule.

The *glomerulus* is a lobulated tuft of convoluted capillary blood-vessels, held together by scanty connective tissue. This capillary network is derived from a small arterial twig, the *afferent vessel*, which enters the capsule, generally at a point opposite to that at which the latter is connected with the tubule; the *efferent vessel* emerges from the capsule at the same point. The afferent vessel is usually the larger of the two (figs. 1158, 1159).

Bowman's capsule is the blind expanded end of the renal tubule, indented for the reception of the glomerulus. It consists of a basement-membrane, lined by a single layer of flattened epithelial cells. Thus between the glomerulus and the outer layer of the capsule there is a space lined by a continuous layer of squamous cells; this cavity varies in size according to the state of secretion and the amount of fluid present in it. In the fœtus and young subject the lining epithelial cells are polyhedral or columnar.

Each *renal tubule* consists of the following parts: (1) *Bowman's capsule*, already described, (2) a constricted portion, the *neck*, (3) the *first convoluted tubule*, (4) the *spiral tubule*, which takes a course towards the medulla, (5) the *descending limb of Henle's loop*, narrower than the preceding, and running into the medullary substance, where it turns to form (6) the *loop of Henle*, (7) the *ascending limb of Henle's loop*, broader than the descending limb, which re-enters the cortical substance, (8) an angular segment, the *irregular or zig-zag tubule*, (9) the *second convoluted tubule*, (10) the *junctional tubule*, which opens into (11), the *collecting tubule* (fig. 1157).

Fig. 1160.—A longitudinal section through the descending limb of Henle's loop.



a. Membrana propria. *b*. Epithelium.

The *straight or collecting tubules* commence in the medullary rays of the cortex; they unite at short intervals with one another; the terminal tubes present a considerable increase in calibre, and are known as the *ducts of Bellini*; they finally open on the summit of a papilla.

Structure of the renal tubules.—The renal tubules consist of a basement-membrane lined by epithelium. In the neck the epithelium is continuous with that lining Bowman's capsule, and like it consists of flattened cells each containing an oval nucleus (fig. 1161). The two convoluted tubules, the spiral and zig-zag tubules, and the ascending limb of Henle's loop are lined by a type of epithelium which is histologically similar in all. The cells are somewhat columnar in shape and dovetail into one another on their lateral aspects. Each has a striated border next the lumen of the tube; its substance is granular, the granules in the outer portion being arranged in vertical rows. The nucleus is spherical and situated about the centre of the cell. In the descending limb of Henle's loop the epithelium resembles that found in Bowman's capsule and the

commencement of the tube, consisting of flat, clear epithelial plates, each with an oval nucleus (fig. 1160). The nuclei alternate on opposite surfaces of the tubule so that the lumen remains fairly constant.

Fig. 1161.—A radial section through the cortex of a human kidney. Stained with hæmatoxylin and eosin. ×100.

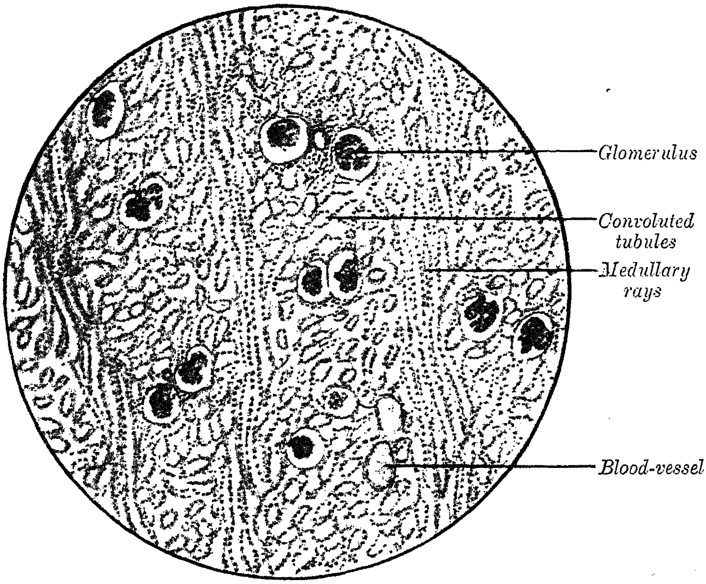
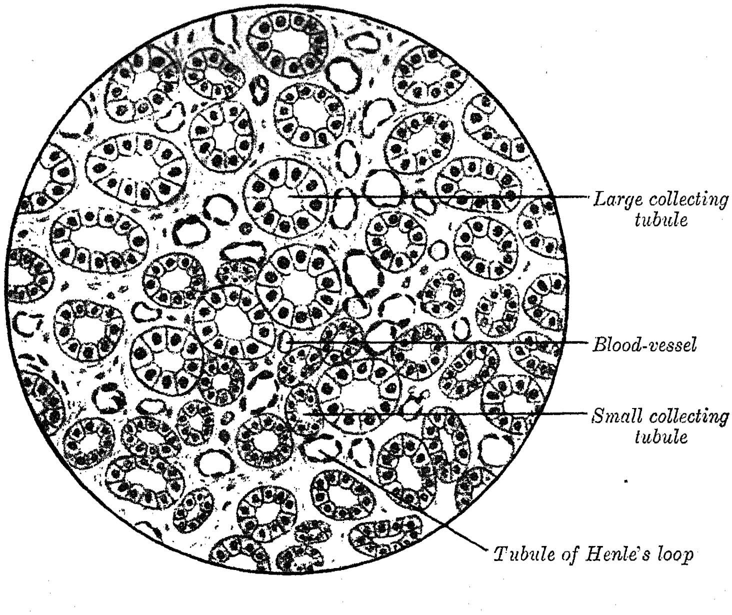


Fig. 1162.—A transverse section through a pyramid of a human kidney. Stained with hæmatoxylin and eosin. ×400.



In the collecting tubule the epithelium is clear and cubical: in its papillary portion the cells are columnar and transparent (fig. 1162).

The **renal blood-vessels**.—Before entering the kidney, each artery divides into four or five branches which at the hilum lie mainly between the renal vein and renal pelvis, the vein being in front, the pelvis behind; one branch usually lies behind the pelvis. Each

vessel gives off some small branches to the suprarenal glands, to the ureter, and to the surrounding cellular tissue and muscles. One or two *accessory renal arteries* may arise from the abdominal aorta, either above or below the renal artery. Such vessels do not enter the hilum, but pierce the upper or lower parts of the kidney. The branches of the renal artery, while in the sinus, give off a few twigs for the nutrition of the surrounding tissues, and end in the *arteriæ propriæ renales*, which enter the kidney proper in the renal columns. These pass between the renal pyramids, and may be called *interlobar arteries* (Gross*). They run a short course, and divide and subdivide rapidly at acute angles as they penetrate the kidney substance, producing, when injected by barium sulphate and examined by means of *x*-rays, a treelike appearance. From the smallest branches of the tree, near the surface of the kidney, there spring a large number of straight arteries (*intralobular*), arranged vertically to the surface. Each of these gives off a number of lateral branches, afferent vessels of the glomeruli, or *glomerular arteries*. Each intralobular artery with its branches and associated glomeruli resembles a string of red currants.

From the capillaries of each glomerulus an efferent vessel, smaller than the afferent vessel, arises and divides to form a second set of capillaries which run between the tubules and are called *intertubular capillaries*. These unite to form *intralobular veins* which discharge into the tributaries of the *interlobar veins* running with the interlobar arteries. Each intralobular vein begins beneath the fibrous tunic of the kidney by the convergence of smaller veins, called *venæ stellatæ* because of their appearance as seen from the surface of the organ.

The vascular supply of the medulla of the kidney is relatively scanty, and is derived from branches of the interlobar arteries, and also, to a small extent, from the efferent vessels of the glomeruli adjacent to the medullary substance. The capillaries run a straight course between the collecting tubules, and open into tributaries of the interlobar veins, these finally uniting to form the renal vein.

Nerves of the kidney.—The nerves of the kidney, although small, are about fifteen in number. They have small ganglia developed upon them, and are derived from the renal plexus, which is formed by branches from the cœliac plexus, the lower and outer part of the cœliac ganglion and aortic plexus, and from the lesser and lowest splanchnic nerves. The spinal nerves which supply the kidney are derived from the tenth, eleventh, and twelfth thoracic segments of the medulla spinalis. The nerves communicate with the testicular plexus, a circumstance which may explain the occurrence of pain in the testis in affections of the kidney. They accompany the renal artery and its branches, and are distributed to the blood-vessels and to the cells of the urinary tubules.

The *lymphatics* of the kidney are described on p. 772.

Connective tissue, or intertubular stroma.—Although the tubules and vessels are closely packed, a small amount of connective tissue, continuous with the fibrous tunic, binds them firmly together and supports the blood-vessels, lymphatics, and nerves.

Applied Anatomy.—Absence of one kidney is excessively rare ; a more frequent occurence is congenital atrophy of one kidney, where the organ is very small but usually healthy in structure. One or both kidneys may be misplaced as a congenital condition ; if the misplaced kidney is not fixed it is termed a floating kidney. Usually the misplaced organs are misshapen and fixed ; they may be situated higher or lower or further from the middle line than usual ; or they may be displaced into the iliac fossa, over the sacro-iliac joint, on to the promontory of the sacrum, or into the pelvis between the rectum and bladder, or by the side of the uterus. Occasionally the two kidneys are fused together ; the union may be complete, resulting in a disc-shaped kidney from which two ureters descend ; or the lower ends may be connected by a thick mass of renal tissue so that the whole structure presents the form of a horse-shoe. Fused kidneys are usually situated in the middle line of the abdomen but may be misplaced. Pulsation of the abdominal aorta may be transmitted through the part of the 'horse-shoe' kidney which crosses in front of the vessel. In the fœtus the kidney has a lobulated structure (fig. 1155), and traces of this may persist in the adult. Sometimes the pelvis of the kidney is duplicated, and a double ureter is not uncommon.

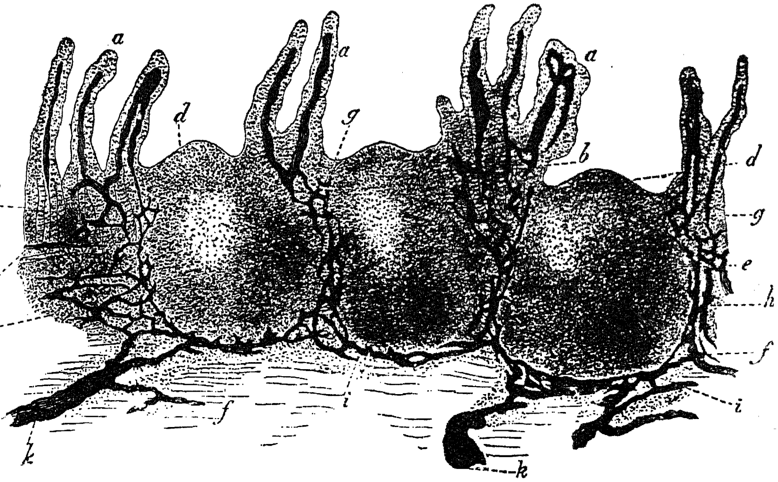
In badly nourished people or in those who have become emaciated, the perinephric fat is deficient and the kidney may become displaced ; this condition, which occurs more frequently in females than in males, on account of the greater laxity of the abdominal walls, is termed movable kidney.

Injuries of the kidney are generally due to some severe crushing force, as from being run over by a heavy waggon or cart, or from the abdomen being compressed between the buffers of two railway carriages. When a laceration occurs on the posterior surface of the organ, infiltration of blood and urine takes place into the retroperitoneal connective tissue ; this is often followed by suppuration, and death may ensue from septic poisoning. When the laceration is in front, the peritoneum may be torn and extravasation of blood and urine may take place into the peritoneal cavity. Death may occur from hæmorrhage or peritonitis. Occasionally, when rupture involves the pelvis of the kidney or the commencement of the ureter, this duct may become blocked, and hydronephrosis follow. Sometimes the kidney may be bruised by blows in the loin, or by being compressed

* For a method of investigating the course of the blood-vessels in the kidney, the reader is referred to an article by L. Gross, *Journal of Medical Research*, vol. xxxvi. 1917.

covered with columnar epithelium; the patches do not, as a rule, possess villi on their free surfaces. They are freely supplied with blood-vessels (fig. 1121), which form an

FIG. 1120.—A vertical section through a human aggregated lymphatic nodule, injected through the lymphatic vessels.



a. Villi with their lacteals. *b.* Intestinal glands. *c.* Muscularis mucosæ. *d.* Cupula or apex of solitary lymphatic nodule. *e.* Mesial zone of nodule. *f.* Base of nodule. *g.* Points of exit of the lacteals from the villi, and entrance into the true mucous membrane. *h.* Retiform arrangement of the lymphatic vessels in the mesial zone. *i.* Course of the latter at the base of the nodule. *k.* Confluence of the lymphatic vessels in the submucous tissue. *l.* Follicular tissue of the latter.

abundant plexus around each nodule and give off fine branches permeating the lymphoid tissue in the interior of the nodule. The plexuses of lymphatic vessels are especially abundant around these patches.

FIG. 1121.—A transverse section through the equatorial plane of three lymphatic nodules of the rabbit.

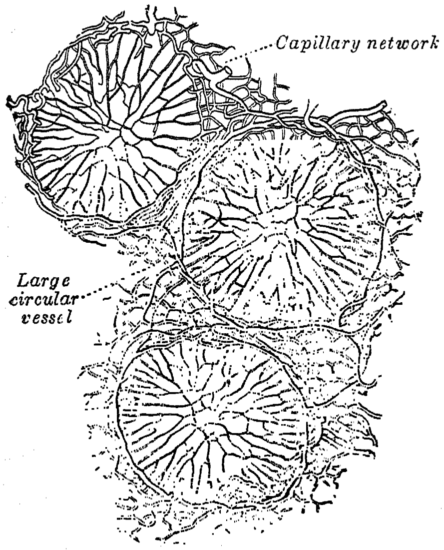
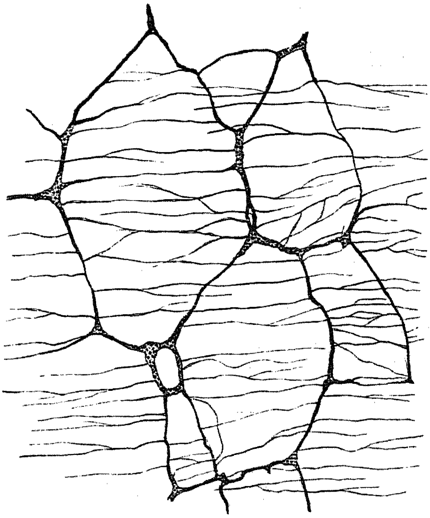


FIG. 1122.—The myenteric plexus of the rabbit. × 50.

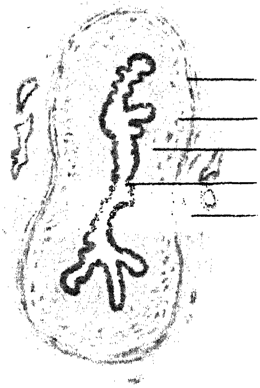


Vessels and Nerves.—The jejunum and ileum are supplied by the superior mesenteric artery, the jejunal and ileal branches of which, having reached the attached border of the bowel, run between the serous and muscular coats, with frequent inosculations, to

At its origin the *right* ureter is usually covered by the descending part of the duodenum ; in its course downwards it lies to the right of the inferior vena cava, and is crossed by the right colic and the ileocolic vessels, while near the superior aperture of the pelvis it passes behind the lower part of the mesentery and the terminal part of the ileum. The *left* ureter is crossed by the left colic vessels, and near the superior aperture of the pelvis passes behind the sigmoid colon and its mesentery.

The *pelvic part* runs at first downwards on the lateral wall of the pelvic cavity, under cover of the peritoneum, and along the anterior border of the greater sciatic notch. It lies in front of the hypogastric artery, and medial to the obturator nerve and the umbilical, obturator, inferior vesical, and middle hæmorrhoidal arteries. Opposite the lower part of the greater sciatic foramen it inclines medialwards, and reaches the lateral angle of the urinary bladder, where it is situated in front of the upper end of the seminal vesicle (and at a distance of about 5 cm. from the opposite ureter) ; here the ductus deferens crosses to its medial side, and the vesical veins surround it. Finally, the ureters run obliquely through the wall of the bladder and open by slit-like apertures into the cavity of that viscus at the lateral angles of the trigone (fig. 1169). When the bladder is distended the openings of the ureters may be about 5 cm. apart, but when it is empty and contracted the distance between them is diminished by one-half. Owing to their oblique course through the coats of the bladder, the upper and lower walls of the terminal portions of the ureters become closely applied to each other when the bladder is distended, and, acting as valves, prevent regurgitation of urine.

FIG. 1163.—A transverse section through the ureter. Stained with hæmatoxylin and eosin. ×5.



In the *female*, the ureter forms, as it lies in relation to the wall of the pelvis, the posterior boundary of a shallow depression named the *ovarian fossa*, in which the ovary is situated. It runs medialwards and forwards beneath the broad ligament of the uterus to reach the lateral aspect of the cervix uteri and upper part of the vagina. It then lies for a short distance in front of the vagina, and finally pierces the wall of the bladder obliquely. In this part of its course it is accompanied for about 2·5 cm. by the uterine artery, which then crosses in front of the ureter and ascends between the two layers of the broad ligament. The ureter is distant about 2 cm. from the side of the cervix of the uterus.*

The ureter is sometimes duplicated on one or both sides, and the two tubes may remain distinct as far as the fundus of the urinary bladder ; they rarely open separately into the bladder cavity.

Structure (fig. 1163).—The ureter is composed of three coats: fibrous, muscular, and mucous.

The *fibrous coat* is continuous at one end with the fibrous tunic of the kidney on the floor of the renal sinus ; while at the other it is lost in the fibrous structure of the bladder.

* J. C. Brash (*British Medical Journal*, Oct. 28, 1922) says :

" The relation of the last portion of the ureter to the vagina is variable. There is usually a portion of the ureter in front of the vagina, lying for a short distance in the connective tissue between the vagina and bladder, and then in the wall of the bladder itself.

" With the vagina and bladder symmetrically related to each other this portion of the ureter is equal on the two sides ; but deviation from the symmetrical position is the rule. The result is an increase of this portion of the ureter on one side and a corresponding decrease on the other. There is frequently no ureter in front of the vagina on one side, and therefore a much longer portion than usual on the other side.

" In the majority of specimens examined, it is the left ureter that has the greatest relation to the vagina, and it is occasionally found crossing the middle line of the vagina. . . . It must not be forgotten, however, that occasionally the position may be reversed."

In the renal pelvis the *muscular coat* consists of two layers, longitudinal and circular: the longitudinal fibres become lost upon the sides of the papillæ at the extremities of the calyces; the circular fibres surround the medullary substance in the same situation. In the ureter proper the muscular fibres are very distinct, and are arranged in three layers: an external longitudinal, a middle circular, and an internal, less distinct than the other two, but having a general longitudinal direction.

The *mucous coat* is smooth, and presents a few longitudinal folds which become effaced by distension. It is continuous with the mucous membrane of the bladder below, while it is prolonged over the papillæ of the kidney above. It consists of fibrous tissue containing many elastic fibres, and covered by transitional epithelium. The continuation of the epithelium over the renal papillæ is columnar in type.

The *arteries* supplying the ureter are branches from the renal, testicular (or ovarian), hypogastric, and inferior vesical arteries.

The *lymphatics* of the ureter are described on p. 772.

The *nerves* are derived from the inferior mesenteric, spermatic (or ovarian), and pelvic plexuses; through these plexuses fibres are derived from the lower three thoracic and first lumbar segments of the medulla spinalis. Small ganglia and isolated ganglion-cells are found in the fibrous and muscular coats.

Applied Anatomy.—Rupture of the ureter occasionally occurs. If it be torn completely across, the urine collects in the retroperitoneal tissues; if it be not completely divided, the lumen of the tube may become strictured, and hydronephrosis or pyonephrosis result. The ureter may be accidentally wounded in some pelvic operations, such as removal of the uterus; if this should happen the divided ends must be sutured together, or failing to accomplish this an attempt may be made to implant the upper end into the bladder. If this cannot be carried out the only alternative is to remove the kidney immediately.

Stones may become impacted in any part of the ureter, but this occurs most commonly either at the point where the tube is crossing the pelvic brim or at where it is passing obliquely through the muscular wall of the bladder. In the former case, an incision with its centre opposite, and 2·5 cm. medial to, the anterior superior iliac spine dividing all the structures down to the peritoneum, enables the operator to reach the ureter by pushing the unopened peritoneum inwards; the stone can then be felt in the ureter, the wall of which is incised, and the stone extracted, free drainage being provided for the escaping urine. When the stone is impacted at the vesical end of the tube a preliminary incision into the bladder is required, and the calculus can be removed by scratching through the mucous membrane overlying it.

The Urinary Bladder (Vesica Urinaria)

The **urinary bladder** (fig. 1164) is a sac which acts as a reservoir for the urine; its size and position vary with the amount of fluid it contains, and also with the state of distension of the neighbouring viscera. "The mean capacity of the living urinary bladder in the male adult is 220 c.c., varying from 120 c.c. to 320 c.c." *

When the empty bladder is firmly contracted it presents the form of a flattened tetrahedron. It has a fundus, a vertex, a superior and an inferior surface. The *fundus* is triangular in shape, and is directed downwards and backwards towards the rectum, from which it is separated by the rectovesical fascia, the vesiculæ seminales, and the terminal portions of the ductus deferentes. The *vertex* is directed forwards towards the upper part of the symphysis pubis, and from it the middle umbilical ligament (urachus) is continued upwards on the back of the abdominal wall to the umbilicus; the peritoneum folded over this ligament forms the middle umbilical fold. The *superior surface* is triangular, covered by peritoneum, and is in relation with the sigmoid colon and some coils of the small intestine. It is bounded on either side by a lateral border which separates it from the inferior surface, and behind by a posterior border, represented by a line joining the two ureters, which intervenes between it and the fundus. The lateral borders run from the ureters to the vertex, and from these borders the peritoneum extends to the walls of the pelvis. On either side of the bladder is a peritoneal depression named the *paravesical fossa* (fig. 1091). The *inferior surface* is directed downwards, and is uncovered by peritoneum. It may be divided into a posterior or prostatic area and two inferolateral surfaces. The prostatic area, somewhat triangular, rests upon and is in direct continuity with the base of the prostate; from it the urethra emerges. The inferolateral portions of the inferior surface are separated in front from the symphysis pubis by a mass of fatty tissue named the *retropubic pad*; behind,

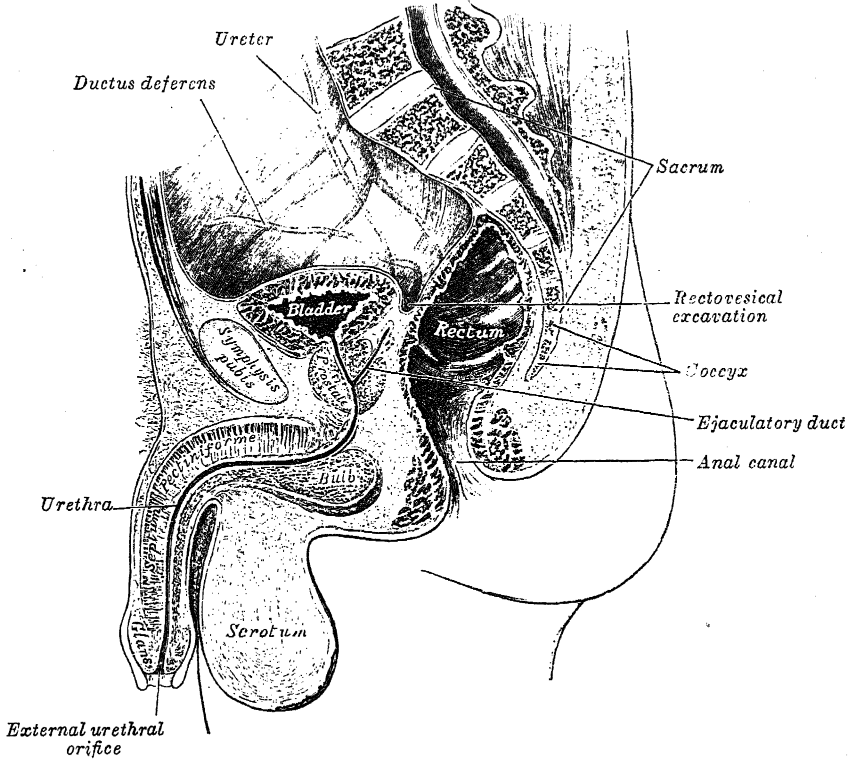
* Ralph Thompson, *Journal of Anatomy*, vol. liii.

they are in contact with the fascia covering the Levatores ani and Obturatores interni.

When the bladder is empty it is placed entirely within the pelvis, below the level of the obliterated hypogastric arteries, and of the portions of the ductus deferentes which are in contact with the lateral wall of the pelvis.

As the bladder fills, its fundus, being more or less fixed, is only slightly depressed; while its superior surface gradually rises into the abdominal cavity, carrying with it its peritoneal covering, and at the same time rounding off the posterior and lateral borders. When the bladder is distended it assumes an ovoid form, the long diameter being directed upwards and forwards. In this condition it presents a posterosuperior, an antero-inferior, and two lateral

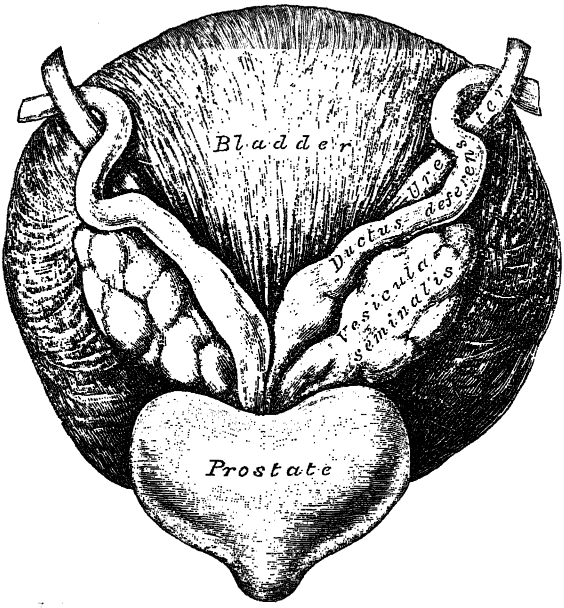
FIG. 1164.—A median sagittal section through the male pelvis.



surfaces, a fundus, and a summit. The posterosuperior surface is directed upwards and backwards, and is covered by peritoneum; its posterior part is separated from the rectum by the rectovesical excavation, while its anterior part is in contact with the coils of the small intestine. The antero-inferior surface is devoid of peritoneum, and rests against the pubic bones and the posterior surface of the anterior abdominal wall. The lower parts of the lateral surfaces are destitute of peritoneum, and are in contact with the lateral walls of the pelvis. The line of peritoneal reflection from the lateral surfaces is raised to the level of the obliterated hypogastric arteries. The fundus undergoes little alteration in position, being only slightly lowered. It exhibits, however, a narrow triangular area, which is separated from the rectum merely by the rectovesical fascia. This area is bounded below by the prostate, above by the rectovesical fold of peritoneum, and laterally by the ductus deferentes. The ductus deferentes frequently come in contact with each other above the prostate, and when this occurs the lower part of the triangular area is obliterated. The line of reflection of the peritoneum from the rectum to the bladder undergoes little or no change when the latter is distended; it is situated about

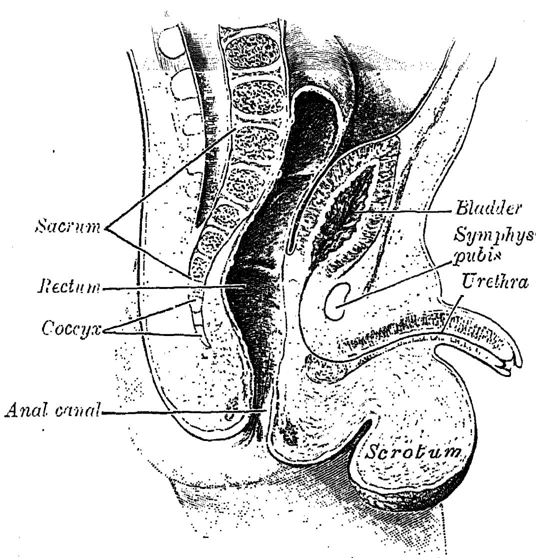
10 cm. from the anus. The summit of the bladder is directed upwards and forwards above the point of attachment of the middle umbilical ligament, and hence the peritoneum, which follows the ligament, forms a pouch of varying depth between the summit and the anterior abdominal wall.

Fig. 1165.—The fundus of the urinary bladder, &c.



In the new-born child (figs. 1166, 1167) the internal urethral orifice is at the level of the upper border of the symphysis pubis; the bladder therefore lies relatively at a much higher level in the infant than in the adult. Its anterior surface 'is in contact with about the lower two-thirds of that part of the abdominal wall which lies between the symphysis pubis and the umbilicus' (Symington *). Its fundus is clothed with peritoneum as far as the level of the internal orifice of the urethra. Although the bladder of the infant is usually described as an abdominal organ, Symington has pointed out that only about one-half of it lies above the plane of the superior aperture of the pelvis. Disse maintains that the internal urethral orifice sinks rapidly during the first three years of life, and then more slowly until the ninth year, after which it remains stationary until puberty, when it again slowly descends and reaches its adult position.

Fig. 1166.—A sagittal section through the pelvis of a new-born male child.



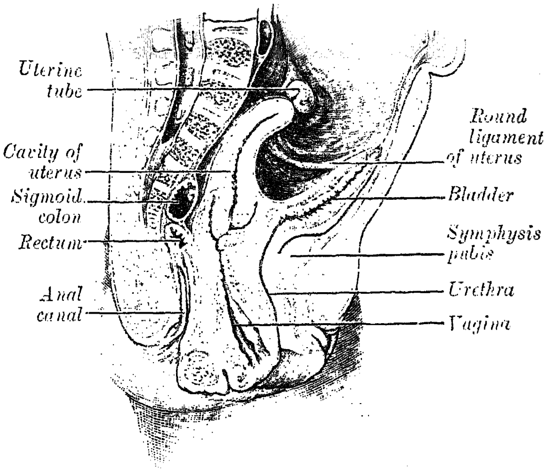
In the female, the bladder is in relation behind with the uterus and the upper part of the vagina (fig. 1168). It is separated from the anterior surface of the body of the uterus by the vesico-uterine excavation, but below the level of this excavation it is connected to the front of the cervix uteri and the upper part of the anterior wall of the vagina by areolar tissue. When the bladder is empty the uterus rests upon its superior surface.

Ligaments.—Each side of the bladder is connected to the tendinous arch or white line of the pelvic fascia (p. 484) by what is known as the vesical layer of the pelvic fascia or *lateral true ligament* of the bladder. Anteriorly the same

* *The Anatomy of the Child.*

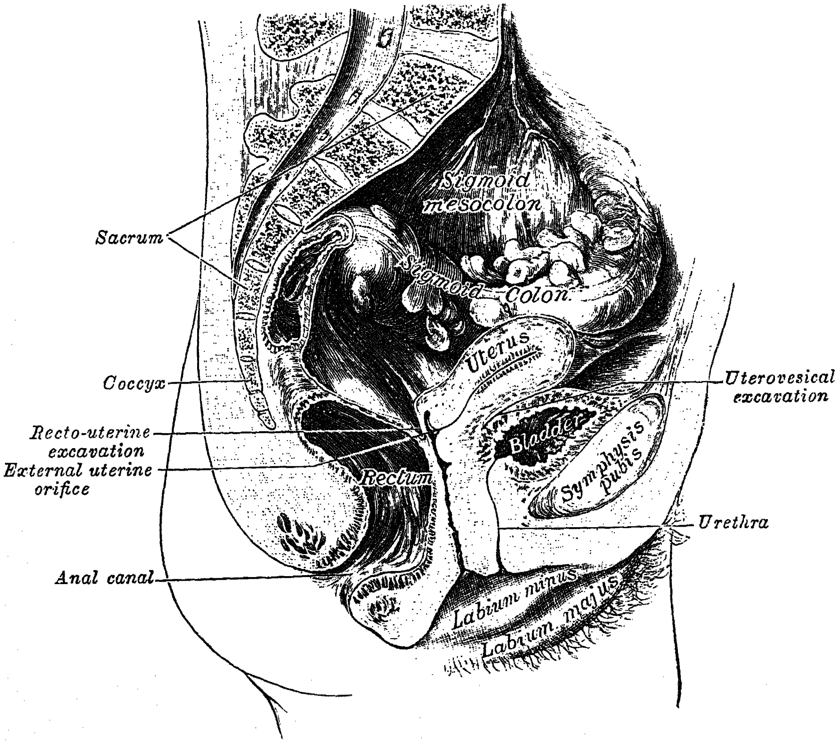
fascia forms two thickened bands, one on either side of the middle line, which pass from the back of the pubic bones to the prostate gland and the front of the bladder; these bands are named the *puboprostatic ligaments*, or *anterior true ligaments* of the bladder. The vertex of the bladder is joined to the umbilicus by the remains of the urachus which forms the *middle umbilical ligament*, a fibromuscular cord, broad at its attachment to the bladder but narrowing as it ascends.

Fig. 1167.—A sagittal section through the pelvis of a new-born female child. Some coils of the small intestine separated the uterus from the bladder.



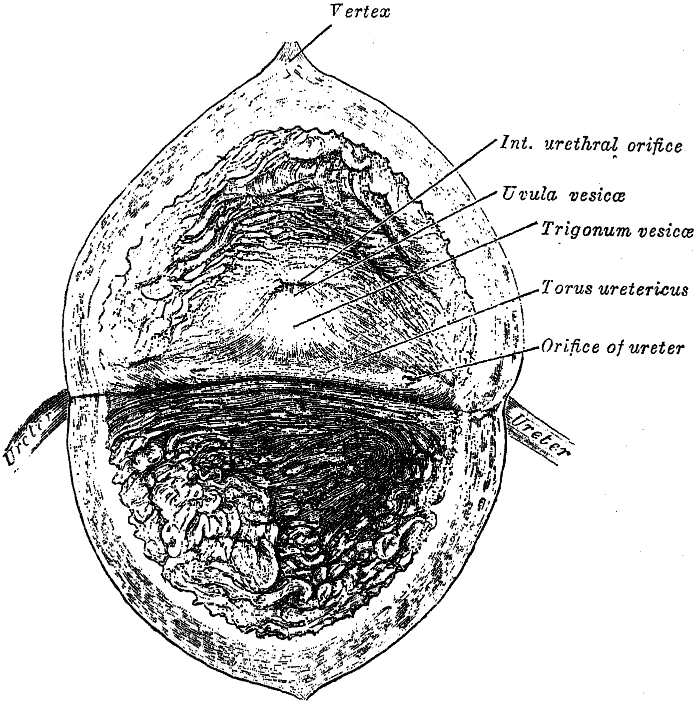
From the superior surface of the bladder the peritoneum is carried off in a series of folds which are sometimes termed the false ligaments of the bladder. Anteriorly there are three folds: the *middle umbilical fold* on the middle umbilical ligament, and two *lateral umbilical folds* on the obliterated hypogastric arteries. The reflections of the peritoneum from the bladder to the side walls of the pelvis form the lateral false ligaments, while the rectovesical or sacrogenital folds (p. 1138) constitute the posterior false ligaments.

Fig. 1168.—A median sagittal section through the female pelvis.



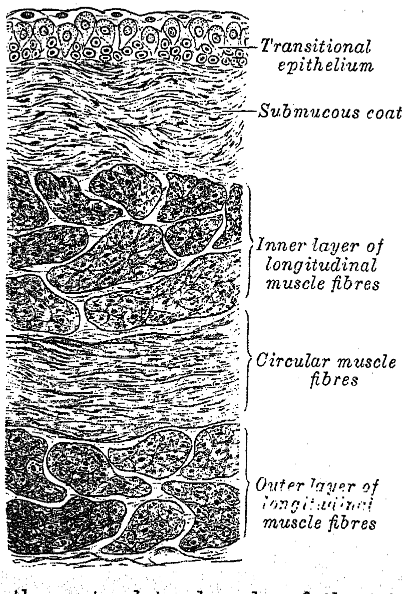
The interior of the bladder (fig. 1169).—The mucous membrane which lines the bladder is, over the greater part of the viscus, loosely attached to the

FIG. 1169.—The interior of the bladder.



muscular coat, and appears folded when the bladder is contracted: the folds are effaced when the bladder is distended. Over a small triangular area, termed the *trigonum vesicæ*, immediately above and behind the internal orifice of the urethra, the mucous membrane is firmly bound to the muscular coat, and is always smooth. The anterior angle of the trigonum vesicæ is formed by the internal orifice of the urethra: its posterolateral angles by the orifices of the ureters. Stretching between the latter openings is a slightly curved ridge, the *torus uretericus*, forming the base of the trigone and produced by an underlying bundle of non-striped muscular fibres. The lateral parts of this ridge extend beyond the openings of the ureters; they are named the *plicæ uretericæ*, and are produced by the terminal portions of the ureters as they traverse obliquely the bladder-wall. When the bladder is illuminated the torus uretericus appears as a pale band, and forms an important guide during the operation of introducing a catheter into the ureter.

FIG. 1170.—A vertical section through the wall of the bladder.



The *orifices of the ureters* are placed at the posterolateral angles of the trigonum vesicæ, and are usually slit-like in form. In the contracted bladder they are about 2·5 cm. apart and about the

same distance from the internal urethral orifice ; in the distended bladder these measurements may be increased to about 5 cm.

The *internal urethral orifice* is placed at the apex of the trigonum vesicæ, in the most dependent part of the bladder, and is usually somewhat crescentic in form ; the mucous membrane immediately behind it exhibits a slight elevation, the *uvula vesicæ*, caused by the middle lobe of the prostate.

Structure (fig. 1170).—The bladder is composed of four coats: serous, muscular, submucous, and mucous.

The *serous coat* is a partial one, and is derived from the peritoneum. It invests the superior surface and the upper parts of the lateral surfaces, and is reflected from these on to the abdominal and pelvic walls.

The *muscular coat* consists of three layers of unstriped muscular fibres: an external and an internal of longitudinal fibres, and a middle of circular fibres.

The fibres of the *external longitudinal layer* arise from the posterior surface of the body of the os pubis in both sexes (*Musculi pubovesicales*), and in the male from the adjacent part of the prostate and its capsule. They pass, in a more or less longitudinal manner, up the inferior surface of the bladder, over its vertex, and then descend along its fundus to become attached to the prostate in the male, and to the front of the vagina in the female. Some of the longitudinal fibres are carried on to the front of the rectum, and are named the *Musculus rectovesicalis*. At the sides of the bladder the fibres are arranged obliquely and intersect one another.

The fibres of the *middle circular layer* are very thinly and irregularly scattered on the body of the organ, and, although to some extent placed transverse to the long axis of the bladder, are for the most part arranged obliquely. Towards the lower part of the bladder, round the internal urethral orifice, they are disposed in a thick circular layer, forming the *Sphincter vesicæ*, which is continuous with the muscular fibres of the prostate.

The *internal longitudinal layer* is thin, and its fasciculi have a reticular arrangement, but with a tendency to assume for the most part a longitudinal direction.

Two bands of oblique fibres, originating behind the orifices of the ureters, converge to the back part of the prostate, and are inserted by means of a fibrous process into the middle lobe of that organ. They are the *muscles of the ureters*, described by Sir C. Bell, who supposed that during the contraction of the bladder they serve to retain the oblique direction of the ureters, and so prevent the reflux of the urine into them.

The *submucous coat* consists of a layer of areolar tissue, connecting together the muscular and mucous coats, and intimately united with the latter.

The *mucous coat* is thin, smooth, and of a pale rose colour. It is continuous above with that of the ureters, and below with that of the urethra; the epithelium covering it is of the transitional variety. The loose texture of the submucous layer allows the mucous coat to be thrown into folds or *rugæ* when the bladder is empty. Over the trigonum vesicæ the mucous membrane is closely attached to the muscular coat, and is not thrown into folds, but is smooth and flat. There are no true glands in the mucous membrane of the bladder, though certain mucous follicles which exist, especially near the neck of the bladder, have been regarded as such.

Vessels and Nerves.—The principal *arteries* of supply to the bladder are the superior, middle, and inferior vesical, derived from the anterior trunk of the hypogastric artery. The obturator and inferior glutæal arteries also send small branches to it, and in the female additional branches are derived from the uterine and vaginal arteries.

The *veins* form a complicated plexus on the inferior surface and fundus near the prostate, and end in the hypogastric veins.

The *lymphatics* are described on p. 772.

The *nerves* of the bladder are (1) fine medullated fibres from the second, third, and fourth sacral nerves, and (2) non-medullated fibres from the hypogastric plexus. They are connected with ganglia in the outer and submucous coats, and are finally distributed, all as non-medullated fibres, to the muscular layer and epithelial lining of the viscus.

Applied Anatomy.—A defect of development, in which the bladder is implicated, is known under the name of *extroversion of the bladder*. In this condition the lower part of the abdominal wall as high as the umbilicus, and the anterior wall of the bladder are wanting, so that the posterior wall of the bladder presents on the abdominal surface, and is pushed forwards by the pressure of the viscera within the abdomen, forming a red vascular tumour on which the openings of the ureters are visible. The penis, except the glans, is rudimentary and is cleft on its dorsal surface, exposing the floor of the urethra, a condition known as *epispadias*. The pelvic bones are also arrested in development (p. 317).

When the bladder is distended, it may be ruptured by violence applied to the abdominal wall, without any injury to the bony pelvis, or it may be torn in cases of fracture of the pelvis. The rupture may be either intraperitoneal or extraperitoneal: that is, may implicate the superior surface of the bladder in the former case, or one of the other surfaces in the latter. Until recently intraperitoneal rupture was uniformly fatal, but now abdominal section and suturing the rent with Lembert's suture are resorted to,

with a very considerable amount of success. The sutures are inserted only through the peritoneal and muscular coats in such a way as to bring the serous surfaces at the margins of the wound into apposition.

The muscular coat of the bladder undergoes hypertrophy in cases in which there is any obstruction to the flow of urine. Under these circumstances the bundles of which the muscular coat consists become much increased in size, and, interlacing in all directions, give rise to what is known as the *fasciculated bladder*. Between these muscular bundles the mucous membrane may bulge out, forming sacculi, constituting the *sacculated bladder*, and in these little pouches phosphatic concretions may collect, forming *encysted calculi*.

Various forms of tumour have been found springing from the wall of the bladder. The commonest innocent tumour is the villous papilloma. Of the malignant tumours, epithelioma is the most common. In doubtful cases the cystoscope proves a valuable aid in diagnosis. This instrument consists of a tube in which is fixed a small electric light, the wires of which run through the shaft of the instrument. Upon introducing this down the urethra, the bladder can be examined with the eye, and a villous growth or other tumour, a calculus, or an ulcer can be detected; or the orifices of the ureters can be examined, and renal hæmaturia diagnosed, and it can be definitely settled from which kidney the blood comes. Again, the presence of a minute tuberculous ulceration near the mouth of the ureter on the affected side may establish the diagnosis, not only of tuberculous kidney, but also of the side in which the disease is located. The cystoscope can be used to catheterise the ureter, for the purpose of obtaining a specimen of urine from either kidney, or to ascertain the condition of both kidneys where it is proposed to remove one. Ureteric bougies opaque to x-rays can be passed and photographed. The pelvis of the kidney can be distended with 25 per cent. sodium bromide through the ureter and its shape photographed.

Puncture of the bladder may be performed either above the symphysis pubis or through the rectum, in both cases without wounding the peritoneum. The former plan is to be preferred, since in puncture through the rectum a permanent fistula may be left from an abscess forming between the rectum and the bladder; or pelvic cellulitis may be set up; moreover, it is exceedingly inconvenient to keep a canula in the rectum. In some cases in performing this operation the rectovesical excavation of the peritoneum has been wounded, inducing fatal peritonitis. Puncture through the rectum, therefore, has been almost completely abandoned in favour of the suprapubic route.

Access to the bladder, for the purpose of removing calculi or an enlarged prostate, is almost always effected by the suprapubic route, the old perineal operation being rarely resorted to. In the female, owing to the shortness of the urethra and its ready dilatability, calculi and foreign bodies and new growths, when of small size, may be removed by the urethral route. Over-dilatation of the female urethra may cause incontinence of urine.

Suprapubic cystotomy is performed by first injecting ten or twelve ounces of some weak antiseptic fluid into the bladder. Then, with or without distending the rectum, a vertical median incision, from 7 to 10 cm. in length, is made in the hypogastric region immediately above the symphysis, and extended between the Pyramidales and Recti until the transversalis fascia is reached. This is divided and some fatty tissue exposed (space of Retzius). Upon separating this, the inferior surface of the bladder will be exposed and will be recognised by its muscular fibres. A needle should be passed through its coat on either side of the spot selected for the opening, and two long pieces of silk inserted. The bladder is incised between these stays, which are held by an assistant and form a useful guide to the opening in the bladder when the fluid has escaped.

It is important that the bladder should be emptied by catheter as a routine measure in women, prior to operations on the lower part of the abdomen or pelvis. Neglect of this precaution has, not uncommonly, led to that viscus being opened by accident. Women especially are apt to acquire an atonic distension of the bladder, and the fact that some quantity of urine has been passed immediately before the operation is no guarantee that the viscus is not distended. If the accident should occur, the bladder wall must be carefully sutured before the peritoneum is opened.

The Male Urethra (fig. 1171)

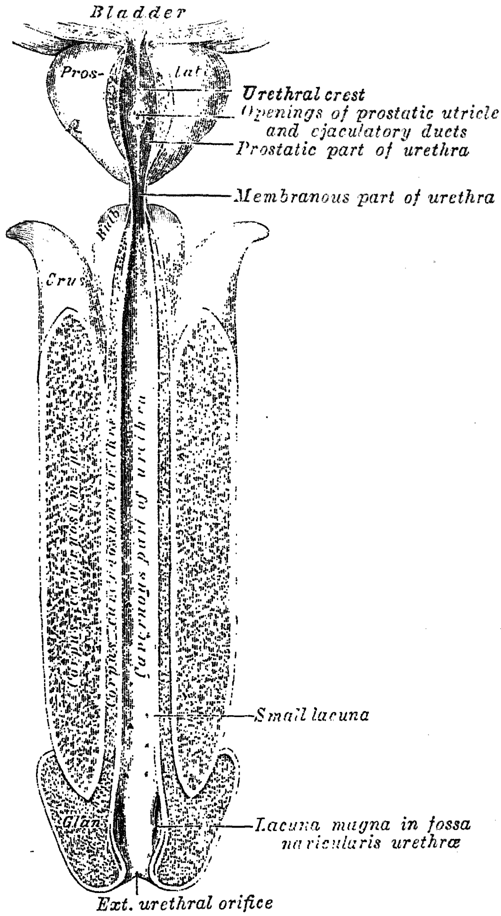
The **male urethra**, from 18 cm. to 20 cm. long, extends from the internal urethral orifice in the urinary bladder to the external urethral orifice at the end of the penis. It is divided into three portions, *prostatic*, *membranous*, and *cavernous*, and presents a double curve in the ordinary relaxed state of the penis (fig. 1164). Except during the passage of fluid along it, the urethral canal is a mere slit or cleft; in the prostatic portion the slit is transversely arched; in the membranous portion, irregular or stellate; in the cavernous portion, transverse; while at the external orifice it is vertical.

The **prostatic portion**, the widest and most dilatable part of the urethra, is about 3 cm. long, and runs almost vertically through the prostate from its base to its apex; it lies nearer the anterior than the posterior surface of the prostate.

It is wider in the middle than at either end, and narrowest below, where it joins the membranous portion; in transverse section it is horseshoe-shaped with the convexity directed forwards.

Upon the posterior wall or floor is a narrow longitudinal ridge, the *urethral crest* (verumontanum) formed by an elevation of the mucous membrane and its subjacent tissue. It is about 15 mm. long, and about 3 mm. high. On either side of the crest is a shallow depression, the *prostatic sinus*, the floor of which is perforated by the *orifices of the prostatic ducts* from the lateral lobes of the prostate; the ducts of the middle lobe open proximal to the crest. At the fore part of the urethral crest is an elevation, the *colliculus seminalis*, on which are the orifice of the prostatic utricle and the openings of the ejaculatory ducts. The *prostatic utricle* (uterus masculinus) is a cul-de-sac about 6 mm. long, which runs upwards and backwards in the substance of the prostate behind the middle lobe. Its walls are composed of fibrous tissue, muscular fibres, and mucous membrane; and numerous small glands open into the lumen of the tube. It is developed from the united lower ends of the Müllerian ducts, and is therefore homologous with the uterus and vagina of the female. The ejaculatory ducts are described on p. 1218.

Fig. 1171.—The male urethra laid open on its anterior (upper) surface.



The **membranous portion** is the shortest, least dilatable, and, with the exception of the external orifice, the narrowest part of the urethra. It runs downwards and forwards, with a slight anterior concavity, from the prostate to the bulb of the urethra, perforating the urogenital diaphragm about 2·5 cm. below and behind the pubic symphysis. The hinder part of the urethral bulb lies in apposition with the inferior fascia of the urogenital diaphragm, but its upper portion diverges somewhat from this fascia; the anterior wall of the membranous urethra is thus prolonged for a short distance in front of the urogenital diaphragm, and measures about 2 cm. in length, while the posterior wall which is between the two fasciæ of the diaphragm is only 1·25 cm. long.

The membranous portion of the urethra is surrounded by the fibres of the Sphincter urethræ membranaceæ. In front of it the deep dorsal vein of the penis enters the pelvis between the transverse ligament of the pelvis and the arcuate pubic ligament; on either side near its termination are the bulbo-urethral glands.

The **cavernous portion** is contained in the corpus cavernosum urethræ. It is about 15 cm. long, and extends from the end of the membranous portion to the external urethral orifice. Commencing below the inferior fascia of the urogenital diaphragm it passes forwards and upwards to the front of the lower part of the symphysis pubis; and then, in the flaccid condition

of the penis, it bends downwards and forwards. It is narrow, with a uniform diameter of about 6 mm. in the body of the penis; it is dilated behind, within the bulb, and again anteriorly within the glans penis, where it forms the *fossa navicularis urethræ*. The bulbo-urethral glands open into the cavernous portion of the urethra about 2·5 cm. in front of the urogenital diaphragm.

The *external urethral orifice* is the most contracted part of the urethra: it is a vertical slit, about 6 mm. long, bounded on either side by a small labium.

The lining membrane of the urethra except in the most anterior part of the tube, presents the orifices of numerous small mucous glands and follicles situated in the submucous tissue, and named the *urethral glands* (Littré). Besides these there are a number of small pit-like recesses, or *lacunæ*, of varying sizes; the orifices of these are directed forwards, and may intercept the point of a catheter in its passage along the canal. One lacuna, larger than the rest, is situated on the upper surface of the fossa navicularis; it is called the *lacuna magna*.

Structure.—The urethra is composed of mucous membrane, supported by a submucous tissue which connects it with the various structures through which it passes.

The *mucous membrane* of the urethra is continuous internally with that of the bladder, and externally with the skin covering the glans penis; it is prolonged into the ducts of the urethral, bulbo-urethral, and prostatic glands; and into the ductus deferentes and vesiculæ seminales, through the ejaculatory ducts. In the cavernous and membranous portions of the urethra it is arranged in longitudinal folds when the tube is empty. Small papillæ are found upon it, near the external urethral orifice; its epithelial lining is of the columnar variety except near the external urethral orifice, where it is squamous and stratified.

The *submucous tissue* consists of a vascular erectile layer; outside this is a layer of unstriped muscular fibres, arranged in a circular direction, which separates the mucous membrane and submucous tissue from the tissue of the corpus cavernosum urethræ.

The lymphatic vessels of the urethra are described on p. 773.

Applied Anatomy.—The urethra may be ruptured by the patient falling astride of any hard substance and striking his perinæum, so that the urethra is crushed against the pubic arch. Bleeding will at once take place from the urethra, and this, together with the bruising in the perinæum and the history of the accident, will point to the nature of the injury. Rupture of the urethra is due in other cases to the perforation of a periurethral abscess. Extravasation of urine most frequently takes place into the perinæum in front of the inferior fascia of the urogenital diaphragm, i.e., under the fascia of Colles. Both these layers of fascia are attached firmly to the ischiopubic rami. It is clear, therefore, that when extravasation of fluid takes place between them, it cannot pass backwards, because the two layers are continuous with each other around the Transversi perinæi superficiales; it cannot extend laterally, on account of the connexion of these layers with the rami of the os pubis and ischium; it cannot find its way into the pelvis, because the opening into this cavity is closed by the urogenital diaphragm, and, therefore, so long as these two layers remain intact, the only direction in which the fluid can make its way is forwards into the areolar tissue of the scrotum and penis, and thence on to the anterior wall of the abdomen. When the pelvis is crushed the urethra may be ruptured behind the urogenital diaphragm; the extravasation of urine then takes place into the extra-peritoneal tissue of the pelvis.

Gonorrhœa is an acute and very prevalent inflammatory infection of the mucous membrane of the urethra. The causative organisms (gonococci) pass through the mucous membrane into the submucous tissue, and most serious complications and results may follow. In most cases the disease remains limited to the part of the urethra in front of the urogenital diaphragm, but in some (about 10 per cent.) the 'posterior urethra' becomes involved in the process, leading to an inflammation of the openings of the prostatic follicles. Such a condition is apt to continue as a very chronic form of prostatitis, and in many cases the infection will spread along the ductus deferentes, giving rise to epididymitis.

The anatomy of the urethra is of considerable importance in connexion with the passage of instruments into the bladder. Otis was the first to point out that the urethra is capable of great dilatation, so that, excepting through the external urethral orifice, an instrument corresponding to 18 English gauge (29 French) can usually be passed without damage. The external orifice of the urethra is not so dilatable, and therefore may require slitting. A recognition of this dilatability caused Bigelow to modify very considerably the operation for crushing a stone in the bladder. In passing catheters, especially fine ones, the point of the instrument should be kept as far as possible along the upper wall of the canal, as otherwise it is very liable to enter one of the lacunæ.

Stricture of the urethra is a disease of very common occurrence, and is generally situated in the cavernous part of the urethra, just in front of the membranous portion but in a very considerable number of cases in the antescrotal part of the canal. The

stricture usually results from the contraction of inflammatory products in the submucous tissue, the result, in the vast majority of all cases, of a prolonged gleet following gonorrhœa. Urethral stricture, however, follows rupture of that tube resulting from falls on the perinæum, and in this variety is very dense, and is a most unsatisfactory condition with regard to treatment. Congenital stricture is also occasionally met with, and in such cases multiple strictures may be present throughout the whole length of the cavernous portion.

Congenital defects of the urethra occur occasionally. The one most frequently met with is where there is a cleft on the floor of the urethra owing to an arrest of union in the middle line. This is known as *hypospadias*, and the cleft may vary in extent. The simplest and by far the most common form is where the deficiency is confined to the glans penis. The urethra ends at the point where the extremity of the prepuce joins the body of the penis, in a small valve-like opening. The prepuce is also cleft on its under surface and forms a sort of hood over the glans. There is a depression on the glans in the position of the normal meatus. This condition produces no disability and requires no treatment. In more severe cases the cavernous portion of the urethra is cleft throughout its entire length, and the opening of the urethra is at the point of junction of the penis and scrotum. The under surface of the penis in the middle line presents a furrow lined by a moist mucous membrane, on either side of which is often more or less dense fibrous tissue stretching from the glans to the opening of the urethra, which prevents complete erection taking place. Great discomfort is induced during micturition, and sexual connexion is impossible. The condition may be remedied by a series of plastic operations. The worst form of this condition is where the urethra is deficient as far back as the perinæum, and the scrotum is cleft. The penis is small and bound down between the two halves of the scrotum, so as to resemble a hypertrophied clitoris. The testes are often retained in the abdomen. The condition of parts, therefore, very much resembles the external organs of generation of the female, and many children the victims of this malformation have been brought up as girls. The halves of the scrotum, deficient of testes, resemble the labia, the cleft between them looks like the orifice of the vagina, and the diminutive penis is taken for an enlarged clitoris. There is no remedy for this condition.

A much more uncommon form of malformation is where there is an apparent deficiency of the upper wall of the urethra; this is named *epispadias*. The deficiency may vary in extent; when it is complete the condition is associated with extroversion of the bladder (p. 1207). In less extensive cases, where there is no extroversion, there is an infundibuliform opening into the bladder. The penis is usually dwarfed and turned upwards, so that the glans lies over the opening.

The Female Urethra (fig. 1168)

The **female urethra** is about 4 cm. long and 6 mm. in diameter. It begins at the internal urethral orifice of the bladder, and runs downwards and forwards behind the symphysis pubis, imbedded in the anterior wall of the vagina. It perforates the urogenital diaphragm and ends at the external urethral orifice, an anteroposterior slit with rather prominent margins, which is situated directly in front of the opening of the vagina and about 2·5 cm. behind the glans clitoridis. Except during the passage of fluid the anterior and posterior walls of the urethra are in apposition, and the lining membrane is thrown into longitudinal folds, one of which, placed on the posterior wall of the canal, is termed the *urethral crest.* Many small *urethral glands* and minute pit-like recesses or *lacunæ* open into the urethra. Near the lower end of the urethra are some small glands which are considered to be the homologues of the prostatic glands of the male; on either side they are grouped together to open into a duct, named the *ductus paraurethralis* (Skene's duct), which runs down in the submucous tissue, and ends in a small aperture on the lateral margin of the external urethral orifice.

Structure.—The urethra consists of three coats: muscular, erectile, and mucous.

The *muscular coat* is continuous with that of the bladder; it extends the whole length of the tube, and consists of circular fibres. In addition to this, between the superior and inferior fasciæ of the urogenital diaphragm, the female urethra is surrounded by the Sphincter urethræ membranaceæ, as in the male.

A thin layer of *spongy erectile tissue*, containing a plexus of large veins, intermixed with bundles of unstriped muscular fibres, lies immediately beneath the mucous coat.

The *mucous coat* is pale; it is continuous externally with that of the vulva, and internally with that of the bladder. It is lined by stratified squamous epithelium, which becomes transitional near the bladder. Its external orifice is surrounded by a few mucous follicles.

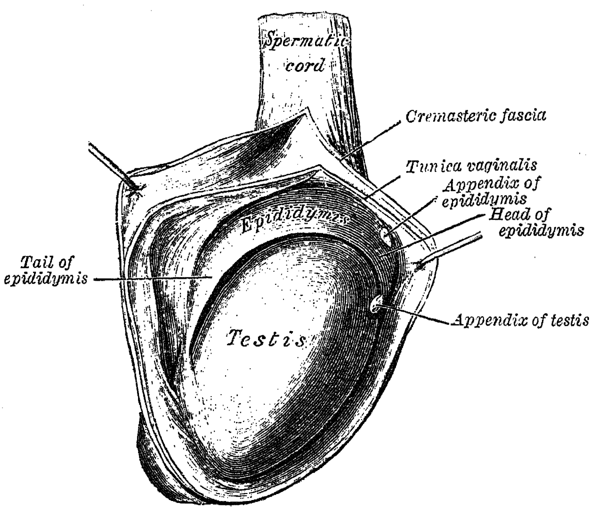
THE MALE GENITAL ORGANS

The male genital organs include the *testes* and *epididymes*, the *ductus deferentes*, the *vesiculæ seminales*, the *ejaculatory ducts*, and the *penis*, together with the following accessory structures, viz. the *prostate* and the *bulbo-urethral glands*.

The Testes

The **testes**, the reproductive glands in the male, are suspended in the scrotum by the spermatic cords, the left testis hanging somewhat lower than its fellow. The average dimensions of the testis are from 4 cm. to 5 cm. in length, 2·5 cm. in breadth, and 3 cm. in the anteroposterior diameter; its weight varies from 10·5 gm. to 14 gm. Each testis is of an oval form (fig. 1172), compressed laterally, and has an oblique position in the scrotum; the upper extremity is directed forwards and a little lateralwards; the lower, backwards and a little medialwards. The anterior border is convex, and looks forwards and downwards; the posterior border, nearly straight, looks backwards and upwards; to it the spermatic cord is attached.

Fig. 1172.—The right testis. Exposed by laying open the tunica vaginalis.



The anterior border, the medial and lateral surfaces, and the extremities of the testis, are convex, free, smooth, and invested by the visceral lamina of the tunica vaginalis (p. 1213). The posterior border receives only a partial investment from that membrane. Lying upon the lateral part of the posterior border is the *epididymis*.

The **epididymis** consists essentially of a tortuous canal which forms the first part of the efferent duct of the testis. This canal is folded on itself and tightly packed into the form of a long, narrow, flattened body attached to the lateral part of the posterior border of the testis. It consists of a central portion, or *body*; an upper enlarged end, the *head* (globus major); and a lower pointed end, the *tail* (globus minor). The head is intimately connected with the upper end of the testis by means of the efferent ductules of the gland; the tail is connected with the lower end by cellular tissue and a reflection of the tunica vaginalis. The lateral surfaces of the head and tail of the epididymis are free and covered by the tunica vaginalis; the body is also invested by it, except at its posterior border; whilst between the body of the epididymis and the lateral surface of the testis is a pouch, named the *sinus of the epididymis* (digital fossa).

The *appendages of the testis and epididymis*.—On the upper extremity of the testis, just beneath the head of the epididymis, is a minute oval, sessile body, the *appendix of the testis* (hydatid of Morgagni); it is the remnant of the upper end of the Müllerian duct. On the head of the epididymis is a small stalked appendage (sometimes duplicated); it is named the *appendix of the epididymis* (pedunculated hydatid), and is usually considered to be a detached efferent duct.

The testis is invested by three tunics: the tunica vaginalis, tunica albuginea, and tunica vasculosa.

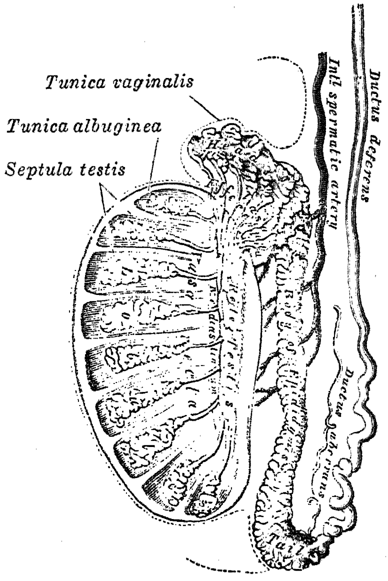
The **tunica vaginalis** is the lower portion of the saccus vaginalis of the peritoneum which, in the fœtus, preceded the descent of the testis from the abdomen into the scrotum. After the testis has reached the scrotum the upper part of the saccus vaginalis, viz. from the abdominal inguinal ring to within a short distance of the testis, contracts and undergoes obliteration. The lower portion remains as a shut sac, which invests the surface of the testis, and is reflected on to the internal surface of the scrotum; hence it may be described as consisting of a visceral and a parietal lamina.

The *visceral lamina* covers the greater part of the testis and epididymis. It lines the sinus of the epididymis and passes as two folds, one from the head and the other from the tail of the epididymis, to the testis; these folds are named the *superior* and *inferior ligaments* of the epididymis. From the posterior border of the testis it is reflected on to the internal surface of the scrotum.

The *parietal lamina* is more extensive than the visceral; it reaches below the testis and extends upwards for some distance in front and on the medial side of the spermatic cord. The inner surface of the tunica vaginalis is smooth, and covered by a layer of endothelial cells. The potential space between the visceral and parietal laminæ constitutes the cavity of the tunica vaginalis.

The obliterated portion of the saccus vaginalis may frequently be seen as a fibrous thread in the areolar tissue in front of the spermatic cord; sometimes this thread may be traced from the upper end of the inguinal canal, where it is connected with the peritoneum, down to the tunica vaginalis; sometimes it is lost on the spermatic cord. In some instances the upper part of the saccus vaginalis is not obliterated, and the peritoneal cavity then communicates with the tunica vaginalis; in others the upper part of the saccus vaginalis may persist as a minute canal leading from the peritoneal cavity to that of the tunica vaginalis.

Fig. 1173.—A vertical section through the testis, to show the arrangement of the ducts. Diagrammatic.



The **tunica albuginea** forms a fibrous covering for the testis. It is a dense membrane, of a bluish-white colour, composed of interlacing bundles of white fibrous tissue. It is covered by the visceral lamina of the tunica vaginalis, except at the head and tail of the epididymis, and along the posterior border of the testis, where the testicular vessels and nerves enter the gland. It is applied to the tunica vasculosa, and, at the posterior border of the testis, is projected into the interior of the gland, forming an incomplete vertical septum, called the *mediastinum testis* (corpus Highmori).

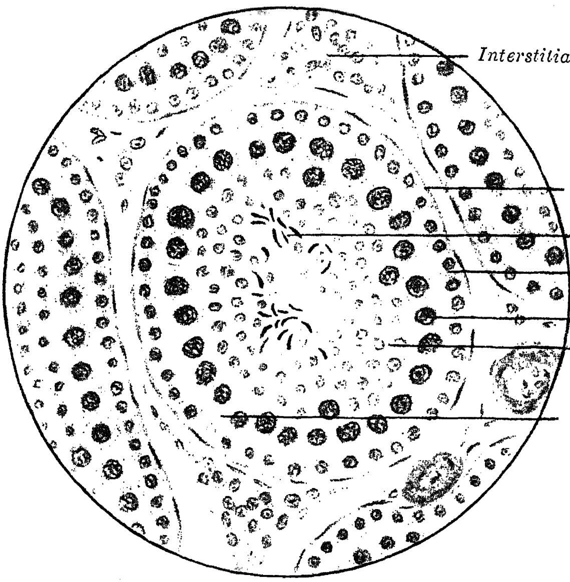
The *mediastinum testis* extends from the upper to near the lower end of the gland, and is wider above than below. From its front and sides are given off numerous imperfect septa (*septula testis*) which radiate towards the surface of the testis, and are attached to the deep aspect of the tunica albuginea. They incompletely divide the testis into a number of cone-shaped lobules (*lobuli testis*). The bases of the lobules are at the surface of the testis, and their apices converge to the mediastinum. The mediastinum supports the vessels and ducts of the testis in their passage to and from the substance of the gland.

The **tunica vasculosa** is the vascular layer of the testis, consisting of a plexus of blood-vessels held together by delicate areolar tissue. It lines the tunica albuginea and clothes the septula testis, and therefore forms an investment to all the lobules of the testis.

Structure.—The glandular structure of the testis consists of the lobuli testis (fig. 1173). Their number, in a single testis, is estimated by Berres at 250, and by Krause at 400. They differ in size according to their position, those in the middle of the testis being larger

and longer. Each lobule consists of from one to three, or more, minute convoluted tubes, the *tubuli seminiferi contorti*. When the tubules have been unravelled by careful dissection under water, they are seen to commence either by free cæcal ends or by anastomotic loops. They are supported by loose connective tissue which contains here and there groups of *interstitial cells* (fig. 1174) containing yellow pigment granules. The total number of tubules is estimated by Lauth at 840, and the average length of each is 70 cm. to 80 cm. Their diameter varies from 0·12 mm. to 0·3 mm. The tubules are pale in colour in early life, but in old age they acquire a deep yellow tinge from containing much fatty matter. Each tubule (fig. 1174) consists of a basement-layer formed of laminated connective tissue containing numerous elastic fibres, with flattened cells between the layers, and covered externally by a layer of flattened epithelioid cells. Within the basement-membrane are epithelial cells arranged in three irregular layers. 1. An outer layer of cubical cells, with small nuclei; some of these enlarge to become *spermatogonia*. The nuclei of some of the spermatogonia may be seen to be in process of indirect division (p. 2), and in consequence of this, daughter cells are formed which constitute the second zone. 2. Larger polyhedral

FIG. 1174.—A transverse section through a part of a human testis. Stained with hæmatoxylin and eosin. ×350.



cells, with clear nuclei, arranged in two or three layers; these are the *intermediate cells* or *spermatocytes*. Most of these cells are in a condition of indirect division, and the cells which result from this division form those of the next layer. 3. The third layer of cells consists of the *spermatids*, each of which becomes a *spermatozoon*. The spermatids are small polyhedral cells, the nucleus of each containing half the usual number of chromosomes. The changes which occur during the conversion of the spermatids into spermatozoa are described and illustrated on p. 45. In addition to these three layers of cells others, termed the *supporting cells*, or *cells of Sertoli*, are seen. They are elongated and columnar, and project inwards from the basement-membrane towards the lumen of the tube. As development of the spermatozoa proceeds, the latter group themselves upon the inner extremities of the supporting cells. Ultimately the spermatozoa are liberated and set free. The structure of the spermatozoa is described on pp. 43, 44.

In the apices of the lobules, the tubules become less convoluted, assume a nearly straight course, and unite at acute angles to form from twenty to thirty larger straight ducts, of about 0·5 mm. in diameter, called tubuli seminiferi recti (fig. 1173).

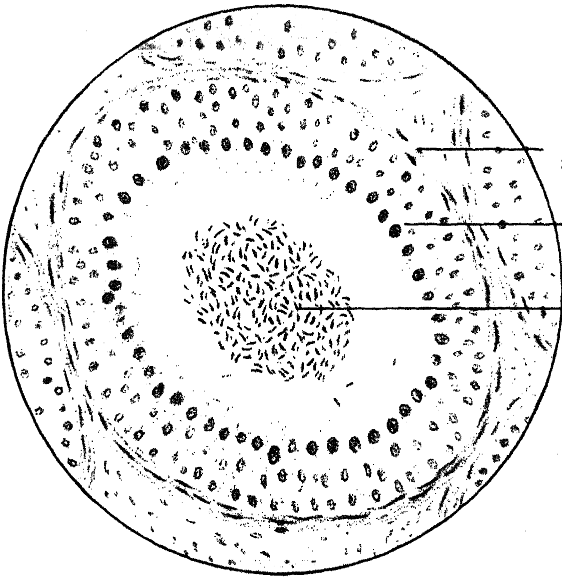
The *tubuli seminiferi recti* enter the fibrous tissue of the mediastinum, and pass upwards and backwards, forming, in their ascent, a close network of anastomosing tubes which are merely channels in the fibrous stroma, lined by flattened epithelium, and having no proper walls; this network is named the *rete testis*. At the upper end of the mediastinum, the vessels of the rete testis terminate in from twelve to twenty ducts, the *ductuli efferentes testis*; they perforate the tunica albuginea, and carry the seminal fluid from the testis to the epididymis. Their course is at first straight; they then become enlarged and exceedingly convoluted, and form a series of conical masses, the *lobules of the epididymis* (coni vasculosi), which together constitute the head of the epididymis. Each lobule

consists of a single convoluted duct, from 15 cm. to 20 cm. in length. Opposite the bases of the lobules the canals open into a single duct, which constitutes, by its complex convolutions, the body and tail of the *epididymis*. When the convolutions are unravelled, this tube measures upwards of 6 metres in length; it increases in diameter and thickness as it approaches the tail of the epididymis where it becomes the ductus deferens. The convolutions are held together by fine areolar tissue, and by bands of fibrous tissue.

The ductuli efferentes and the tube of the epididymis have walls of considerable thickness, on account of the presence in them of muscular tissue which is principally arranged in a circular manner. These tubes are lined by columnar ciliated epithelium (fig. 1175).

Vessels and Nerves.—The *testicular artery* is a branch of the abdominal aorta. It divides into several branches, some of which ramify in the tunica vasculosa, while others traverse the mediastinum testis and, after dividing on the septula testis, supply the tubuli seminiferi. Twigs are also given to the epididymis, and anastomose with the artery of the ductus deferens. The *veins* emerge from the back of the testis and, after receiving tributaries from the epididymis, unite to form the pampiniform plexus (p. 741).

FIG. 1175.—A transverse section through the tube of the human epididymis. Stained with hæmatoxylin and eosin. × 350.



The *lymphatic vessels* of the testis end in the lateral and pre-aortic lymph-glands (p. 773).

The *nerves* accompany the testicular vessels, and are derived from the renal and aortic plexuses, and from the tenth thoracic nerve.

Applied Anatomy.—The descent of the testis may be arrested. It may be retained in the abdomen; or it may be arrested at the abdominal inguinal ring, or in the inguinal canal; or it may just pass out of the subcutaneous inguinal ring without finding its way to the bottom of the scrotum. When retained in the abdomen it gives rise to no signs or symptoms, other than the absence of the testis from the scrotum. When it is retained in the inguinal canal it is subjected to pressure and may become inflamed and painful. The retained testis is probably sexually useless; so that a man in whom both testes are retained (*anorchism*) is sterile, though he may not be impotent. The absence of one testis is termed *monorchism*. When a testis is retained in the inguinal canal it is often complicated with a congenital hernia, the saccus vaginalis of the peritoneum not being obliterated. The testis may descend through the inguinal canal, but may miss the scrotum and assume some abnormal position. The most common form is where it comes to rest in the perinæum. This is known as *perinæal ectopia testis*. When the testis occupies an abnormal position it is very common to find concurrently a congenital hernia or a patent saccus vaginalis.

The testis may be inverted within the scrotum so that its posterior or attached border is directed forwards and the tunica vaginalis is situated behind. Should a hydrocele occur, and tapping be resorted to, the trocar may be thrust into the testis, if care be not taken beforehand to ascertain the position of the gland.

A number of instances of torsion of the spermatic cord, resulting in acute strangulation of the testis, have been recorded. In some it has been attributed to a strain or

twist, and in several patients the condition has been associated with a late descent of the organ. Symptoms of this condition closely simulate those of a strangulated hernia. In consequence of the torsion the circulation is partly arrested and the organ swells and becomes acutely painful, and the condition may be accompanied with shock and vomiting. Gangrene of the testis, however, rarely follows, and the condition if left without operation, ends in atrophy of the organ. Torsion of the body of the testis also sometimes occurs within the tunica vaginalis in those cases in which a persistent mesorchium is present.

Fluid collections of a serous character are frequently found in the scrotum. To these the term *hydrocele* is applied. The most common form is the ordinary *vaginal hydrocele*, in which the fluid is contained in the sac of the tunica vaginalis. In another form, the *congenital hydrocele*, the fluid is in the sac of the tunica vaginalis, but this sac communicates with the general peritoneal cavity owing to the non-obliteration of the upper part of the saccus vaginalis. A third variety, known as an *infantile hydrocele*, occurs in those cases where the saccus vaginalis is obliterated only at or near the abdominal inguinal ring. It resembles the vaginal hydrocele, except as regards its shape, the collection of fluid extending up the cord into the inguinal canal. Fourthly, the saccus vaginalis may be obliterated both at the abdominal inguinal ring and above the epididymis, leaving a central unobliterated portion, which may become distended with fluid, giving rise to a condition known as the *encysted hydrocele of the cord*.

Encysted hydrocele of the epididymis or *spermatocele* is the name given to a cyst found in connexion with the head of the epididymis. Among its contents are found a varying number of spermatozoa, and it is probably a retention cyst of one of the tubules.

The testis requires removal for malignant or tuberculous disease, in cases of large *hernia testis*, and in some instances of incompletely descended or misplaced testis. Castration is in most cases best carried out by the 'high' operation, an incision being made through the skin and fascia in the region of the subcutaneous inguinal ring. The testis, with its deeper coverings, is pushed up into the wound and separated from the scrotal tissues. The cord is then isolated, and an aneurysm needle, armed with a ligature, passed through it, as high as is thought necessary, and the cord tied and divided. In cases of malignant and tuberculous disease, it is desirable to open the inguinal canal and tie the cord as near the abdominal ring as possible. When removing the testis in this manner the tunica vaginalis is not opened and its folds of reflection to the scrotal tissues do not need division. The whole of the tunica vaginalis is thus removed with the cord and its coverings.

The Ductus Deferens

The **ductus deferens** (vas deferens) is the continuation of the canal of the epididymis. Commencing at the lower part of the tail of the epididymis, it is at first very tortuous, but gradually becoming less twisted it ascends along the posterior border of the testis and medial side of the epididymis, and then runs upwards in the posterior part of the spermatic cord, and traverses the inguinal canal to the abdominal inguinal ring. Here it separates from the other structures of the spermatic cord, curves round the lateral side of the inferior epigastric artery, and ascends for about 2·5 cm. in front of the external iliac artery. It is next directed backwards and slightly downwards, and, crossing the external iliac vessels obliquely, enters the pelvic cavity, where it is continued backwards between the peritoneal membrane and the lateral wall of the pelvis, and on the medial side of the obliterated umbilical artery, the obturator nerve and vessels, and the vesical vessels (fig. 1163). It then crosses in front of the ureter (fig. 1175), and, reaching the medial side of this tube, bends at an acute angle, and runs medialwards and slightly forwards between the fundus of the bladder and the upper end of the seminal vesicle. Reaching the medial side of the seminal vesicle, it is directed downwards and medialwards in contact with it, and gradually approaches the opposite ductus. Here it lies between the fundus of the bladder and the rectum, where it is enclosed, together with the seminal vesicle, in a sheath derived from what is known as the recto-vesical portion of the pelvic fascia. Lastly, it passes downwards to the base of the prostate, and is joined at an acute angle by the duct of the seminal vesicle to form the ejaculatory duct, which traverses the prostate behind its middle lobe and opens into the prostatic portion of the urethra, close to the orifice of the prostatic utricle. Owing to the thickness of its wall, the ductus deferens feels hard and cord-like when grasped by the finger and thumb. Its canal in the greater part of its extent is of extremely small calibre, but at the fundus of the bladder it becomes dilated and tortuous, and this portion is termed the *ampulla*; its terminal portion, which joins the duct of the seminal vesicle, is again greatly diminished in calibre.

Ductuli aberrantes.—A long narrow tube, the *ductulus aberrans inferior* (vas aberrans of Haller), is frequently found connected with the lower part of the canal of the epididymis, or with the commencement of the ductus deferens. Its length, when it is uncoiled, varies from 5 cm. to 35 cm., and it may be dilated towards its blind extremity, or may be of uniform diameter throughout. Its structure is similar to that of the ductus deferens. Occasionally it is found unconnected with the epididymis. A second tube, the *ductulus aberrans superior*, occurs in the head of the epididymis, and is connected with the rete testis.

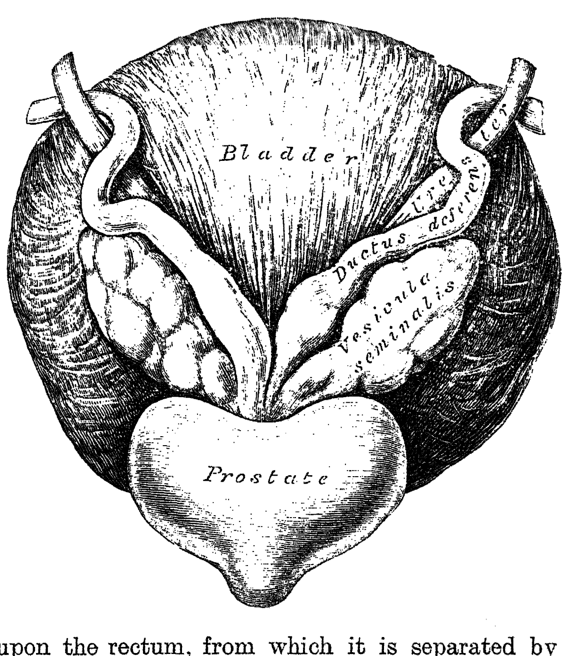
Paradidymis (organ of Giraldès).—This term is applied to a small collection of convoluted tubules, situated in front of the lower part of the spermatic cord above the head of the epididymis. These tubes are lined with columnar ciliated epithelium, and probably represent the remains of a part of the Wolffian body.

Structure.—The ductus deferens consists of three coats: (1) an external or areolar coat; (2) a muscular coat, which in the greater part of the tube consists of two layers of unstriped muscular fibres: an outer, longitudinal in direction, and an inner, circular; but at the commencement of the ductus there is a third layer, consisting of longitudinal fibres, and placed between the circular stratum and the mucous membrane; (3) an internal, or mucous coat, which is pale, and arranged in longitudinal folds. The mucous coat is lined by columnar epithelium which is non-ciliated throughout the greater part of the tube; a variable portion of the testicular end of the tube is lined by two strata of columnar cells, those of the superficial layer being ciliated.

The Vesiculæ Seminales and Ejaculatory Ducts

The **vesiculæ seminales** (fig. 1176) are two sacculated pouches, placed between the fundus of the bladder and the rectum. Each vesicle is about 5 cm. long, and is somewhat pyramidal in form, the broad end being directed backwards, upwards, and lateralwards. It consists of a tube, coiled upon itself, and giving off several irregular diverticula (fig. 1177); the separate coils, as well as the diverticula, are connected together by fibrous tissue. When uncoiled, the tube is about the diameter of a quill, and varies in length from 10 cm. to 15 cm.; it ends above in a cul-de-sac; its lower extremity becomes constricted into a narrow straight duct, which joins with the corresponding ductus deferens to form the ejaculatory duct. The *anterior surface* is in contact with the fundus of the bladder, extending from near the termination of the ureter to the base of the prostate. The *posterior surface* rests upon the rectum, from which it is separated by the rectovesical fascia. The vesicles diverge from each other above, and are in relation with the ductus deferentes and the terminations of the ureters, and are partly covered by peritoneum; each is enveloped in a dense fibromuscular sheath. Along the medial margin of each vesicle runs the ampulla of the ductus deferens.

Fig. 1176.—The fundus of the bladder with the vesiculæ seminales, &c.



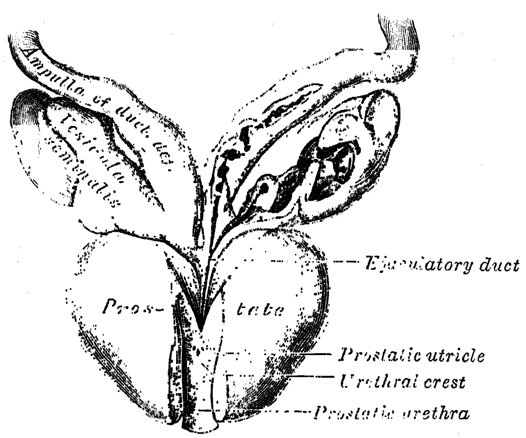
Structure.—The vesiculæ seminales are composed of three coats: an *external or areolar coat*; a *middle or muscular coat*, thinner than that of the ductus deferens and arranged in two layers, an outer longitudinal and an inner circular; an *internal or mucous coat*, which is pale, of a whitish-brown colour, and presents a delicate reticular structure. The epithelium is columnar, and in the diverticula goblet-cells are present, the secretion of which is added to the seminal fluid.

Vessels and Nerves.—The *arteries* supplying the vesiculæ seminales are derived from the middle and inferior vesical, and the middle hæmorrhoidal arteries. The *veins* and *lymphatics* accompany the arteries. The *nerves* are derived from the pelvic plexuses.

Applied Anatomy.—The vesiculæ seminales are often the seat of an extension of the disease in cases of tuberculosis of the testis, and should always be examined from the rectum, before deciding to perform castration in this affection. They also become affected in chronic posterior urethritis of gonorrhœal origin. An abscess of the vesicula seminalis may rupture into the peritoneal cavity and cause fatal peritonitis.

The **ejaculatory ducts** (fig. 1177) are two in number, one on either side of the middle line. Each is formed by the union of the duct of the vesicula seminalis with the terminal part of the ductus deferens, and is nearly 2 cm. long. They commence at the base of the prostate, run forwards and downwards between the middle and lateral lobes, pass along the sides of the prostatic utricle, and end on the colliculus seminalis in slit-like orifices on, or just within, the margins of the opening of the prostatic utricle (p. 1209). The ducts diminish in size, and also converge, towards their terminations.

FIG. 1177.—The vesiculæ seminales and the ampullæ of the ductus deferentes. Anterior aspect. The anterior walls of the left ampulla, left seminal vesicle, and prostatic urethra have been cut away.



Structure.—The coats of the ejaculatory ducts are extremely thin. They are: an *outer fibrous layer*, which is almost entirely lost after the entrance of the ducts into the prostate; a *layer of muscular fibres*, consisting of a thin outer circular, and an inner longitudinal layer; and *mucous membrane.*

THE SPERMATIC CORD AND ITS COVERINGS

When the testis descends through the abdominal wall into the scrotum, it drags its vessels and nerves and the ductus deferens with it. These structures meet at the abdominal inguinal ring and together form the *spermatic cord* (*funiculus spermaticus*) which suspends the testis in the scrotum, and extends from the abdominal inguinal ring to the posterior border of the testis; the left spermatic cord is a little longer than the right.

The spermatic cord traverses the inguinal canal (p. 481) and in so doing is covered by the different layers which form the abdominal wall. These coverings extend downwards into the wall of the scrotum and are named, from within outwards, the infundibuliform, cremasteric and intercrural fasciæ.

The *infundibuliform fascia* is a thin layer which loosely invests the cord, and is derived from the transversalis fascia (p. 480).

The *cremasteric fascia* consists of a number of muscular fasciculi, united to one another by areolar tissue; the muscular fasciculi constitute the Cremaster and are continuous with the Obliquus internus abdominis (p. 475).

The *intercrural fascia* (external spermatic fascia) is a thin fibrous membrane continuous above with the tendon of the Obliquus externus abdominis, and prolonged downwards from the crura of the subcutaneous inguinal ring (p. 472).

Structure of the spermatic cord.—The spermatic cord is composed of arteries, veins, lymphatics, nerves, and the ductus deferens, connected together by areolar tissue.

The *arteries* of the spermatic cord are: the testicular artery, the external spermatic artery, and the artery of the ductus deferens.

The *testicular artery*, a branch of the abdominal aorta, escapes from the abdominal cavity at the abdominal inguinal ring, and accompanies the other constituents of the spermatic cord along the inguinal canal and through the subcutaneous inguinal ring into

the scrotum. It then descends to the testis, and, becoming tortuous, divides into several branches, two or three of which accompany the ductus deferens and supply the epididymis, anastomosing with the artery of the ductus deferens; the others supply the substance of the testis.

The *external spermatic artery* (cremasteric artery) is a branch of the inferior epigastric artery. It supplies the coverings of the spermatic cord, and anastomoses with the testicular artery.

The *artery of the ductus deferens*, a branch of the superior vesical artery, is a long slender vessel which accompanies the ductus deferens, ramifying upon its coats, and anastomosing with the testicular artery near the testis.

The *testicular veins* emerge from the back of the testis, and receive tributaries from the epididymis: they unite and form a convoluted plexus, the *plexus pampiniformis*, which constitutes the chief mass of the cord; the vessels composing this plexus are very numerous, and ascend in front of the ductus deferens; below the subcutaneous inguinal ring they unite to form three or four veins, which pass along the inguinal canal, and, entering the abdomen through the abdominal inguinal ring, coalesce to form two veins. These again unite to form a single vein, which opens on the right side into the inferior vena cava, at an acute angle, and on the left side into the left renal vein, at a right angle.

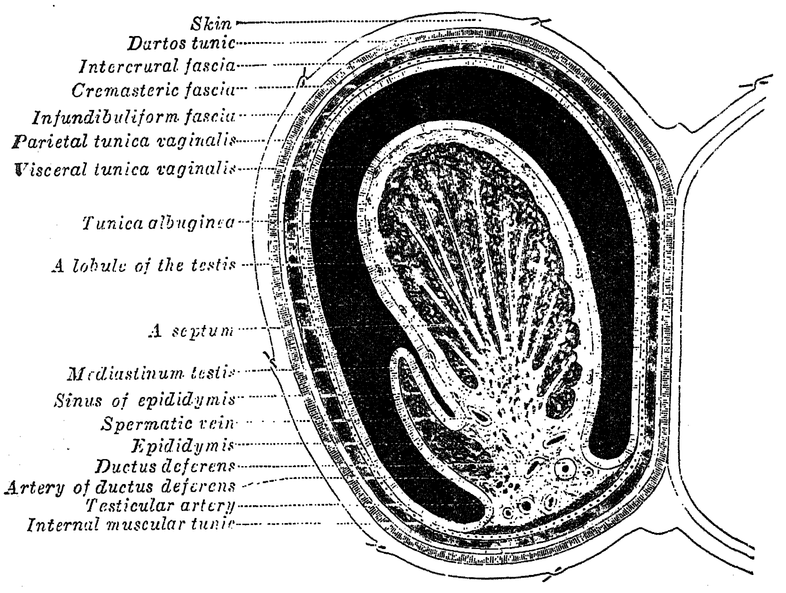
The *lymphatic vessels* of the testis are described on p. 773.

The *nerves* are the spermatic plexus of the sympathetic, joined by filaments from the pelvic plexus which accompany the artery of the ductus deferens.

The Scrotum

The *scrotum* is a cutaneous pouch containing the testes and the lower parts of the spermatic cords, and placed below the pubic symphysis in front of the upper parts of the thighs. It is divided on its surface into a right and

Fig. 1178.—A tranverse section through the left half of the scrotum and the left testis. The sac of the tunica vaginalis is represented in a distended condition. Diagrammatic. (Delépine.)



a left portion by a ridge, or *raphe*, which is continued forwards to the under surface of the penis, and backwards along the middle line of the perinæum to the anus; the left portion hangs lower than the right, in correspondence with the greater length of the left spermatic cord. The external appearance varies under different circumstances: thus, under the influence of warmth, and in old and debilitated persons, the scrotum is elongated and flaccid; but, under the influence of cold, and in the young and robust, it is short, corrugated, and closely applied to the testes. It consists of the skin and the dartos tunic, together with the intercrural, cremasteric and infundibuliform fasciæ, already

described in connexion with the spermatic cord. Within the infundibuliform fascia is the parietal lamina of the tunica vaginalis (fig. 1178).

The *skin* is very thin, of a brownish colour, and generally thrown into folds or rugæ. It is beset with thinly scattered, crisp hairs, the roots of which are visible through the skin; it is provided with sebaceous follicles, the secretion of which has a peculiar odour.

The *dartos tunic* is a thin layer of non-striped muscular fibres, continuous, around the base of the scrotum, with the superficial fascia of the groin and of the perinæum. It sends inwards a septum, which connects the raphe to the under surface of the root of the penis, and divides the scrotal pouch into two cavities for the testes. The dartos tunic is closely united to the skin, but is connected with the subjacent parts by delicate areolar tissue, upon which it glides with the greatest facility.

Vessels and Nerves.—The *arteries* supplying the scrotum are: the superficial and deep external pudendal branches of the femoral artery, the posterior scrotal branches of the perinæal artery, and the cremasteric branch from the inferior epigastric artery. The *veins* follow the course of the corresponding arteries. The *lymphatics* end in the inguinal lymph-glands. The *nerves* are the ilio-inguinal and lumbo-inguinal branches of the lumbar plexus, the two posterior scrotal branches of the perinæal nerve, and the pudendal branch of the posterior femoral cutaneous nerve.

Applied Anatomy.—The scrotum forms an admirable covering for the protection of the testes. These bodies, lying suspended and loose in the cavity of the scrotum and surrounded by serous membrane, are capable of great mobility, and can therefore easily slip about within the scrotum, and thus avoid injuries from blows or squeezes. The skin of the scrotum is very elastic and capable of great distension, and on account of the looseness and amount of subcutaneous tissue, the scrotum becomes greatly enlarged in cases of œdema, to which this part is especially liable as a result of its dependent position. The scrotum is occasionally the seat of epithelioma; this is no doubt due to the rugæ on its surface, which favour the lodgment of dirt, and this, producing irritation, is the exciting cause of the disease, which is especially common in chimney-sweeps from the lodgment of soot. The disease is very much less common than it used to be; this is probably due to the better hygienic conditions of the working classes. The scrotum is also the part most frequently affected by elephantiasis.

On account of the looseness of the subcutaneous tissue, large extravasations of blood may take place from very slight injuries. It is therefore generally recommended never to apply leeches to the scrotum, since they may lead to ecchymosis, but rather to puncture one or more of the superficial veins of the scrotum in cases where local blood-letting from this part is judged to be desirable. The muscular fibres in the dartos tunic cause contraction and considerable diminution in the size of a wound of the scrotum, as after the operation of castration, and are of assistance in keeping the edges together, and covering the exposed parts.

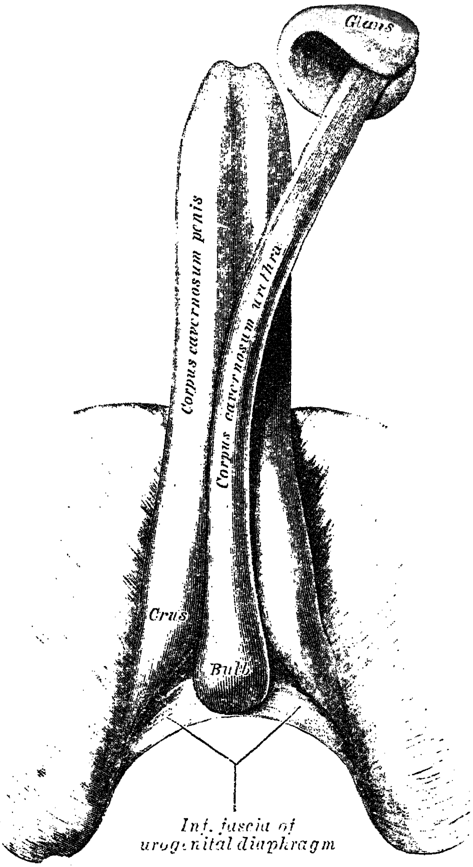
The Penis

The **penis** is a pendulous organ suspended from the front and sides of the pubic arch and containing the greater part of the urethra. In the flaccid condition it is cylindrical in shape, but when erect it assumes the form of a triangular prism with rounded angles, one side of the prism forming the dorsum of the penis. It is composed of three cylindrical masses of cavernous tissue bound together by fibrous tissue and covered with skin. Two of the masses are placed side by side, and are known as the *corpora cavernosa penis*; the third, median in position and beneath the other two, is traversed by the cavernous part of the urethra, and is termed the *corpus cavernosum urethræ* (figs. 1179, 1180).

The **corpora cavernosa penis** form the greater part of the substance of the penis. Throughout the anterior three-fourths of their extent they lie in apposition with one another, separated only by the septum of the penis; behind, they diverge in the form of two tapering processes, which are known as the *crura of the penis*, and are firmly connected to the rami of the pubic arch. Traced from behind forwards each crus begins as a blunt-pointed process in front of the tuberosity of the ischium. Just before it meets its fellow it presents a slight enlargement, named by Kobelt the *bulb of the corpus cavernosum penis*. Beyond this point the crus undergoes a constriction and merges into the corpus cavernosum proper, which retains a uniform diameter to its anterior end. Each corpus cavernosum penis ends abruptly in a round extremity a short distance from the point of the penis.

The corpora cavernosa penis are surrounded by a strong fibrous envelope consisting of superficial and deep fibres. The superficial fibres are longitudinal in direction, and form a single tube which encloses both corpora; the deep fibres are arranged circularly round each corpus, and form by their junction in the median plane the *septum of the penis*. This septum is thick and complete behind, but is imperfect in front, where it consists of a series of vertical bands arranged like the teeth of a comb; it is therefore named the *septum pectiniforme*.

Fig. 1179.—The constituent cavernous cylinders of the penis. The glans penis and the anterior part of the corpus cavernosum urethræ are detached from the corpora cavernosa penis and turned to one side.



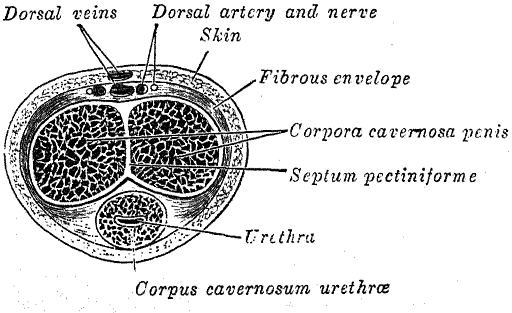
The **corpus cavernosum urethrae** (corpus spongiosum) contains the cavernous part of the urethra. Behind, it is expanded to form the urethral bulb, and lies in apposition with the inferior fascia of the urogenital diaphragm, from which it receives a fibrous investment. The urethra enters the bulb nearer to the upper than to the lower surface. On the lower surface of the bulb there is a median sulcus, from which a thin fibrous septum projects into the substance of the bulb and divides it imperfectly into two lateral lobes or *hemispheres*.

The portion of the corpus cavernosum urethræ in front of the bulb lies in a groove on the under surface of the conjoined corpora cavernosa penis. It is cylindrical in form and tapers slightly from behind forwards. Its anterior end suddenly expands to form an obtuse cone, named the *glans penis*.

For descriptive purposes it is convenient to divide the penis into three regions: the root, the body, and the extremity.

The **root** of the penis is triradiate in form, consisting of the diverging crura, one on either side, and the median urethral bulb. Each crus is covered by the Ischiocavernosus, while the bulb is surrounded by the Bulbocavernosus. The root of the penis lies in the perinæum between the inferior fascia of the urogenital diaphragm and the fascia of Colles. In addition to being attached to the fasciæ and the pubic rami, it is bound to the front of the symphysis pubis by the fundiform and suspensory ligaments. The *fundiform ligament* springs from the front of the sheath of the Rectus abdominis and the linea alba; it splits into two fasciculi which pass one on either side

Fig. 1180.—A transverse section through the penis.



of the penis and unite below with the septum of the scrotum. The *suspensory ligament* is triangular in shape; it is attached above to the symphysis pubis; below, it blends with the fibrous envelope of the corpora cavernosa penis.

The **body** of the penis extends from the root to the anterior end of the corpora cavernosa penis. In the body the corpora cavernosa are intimately bound to one another; a shallow groove which marks their junction on the upper surface lodges the deep dorsal vein of the penis, while a deeper and wider groove between them on the under surface contains the corpus cavernosum urethræ. The body is ensheathed by fascia, which is continuous above with the fascia of Scarpa and below with the dartos tunic of the scrotum and the fascia of Colles.

The **extremity** is formed by the glans penis, the expanded anterior end of the corpus cavernosum urethræ. The glans penis is somewhat conical in shape and its concave base covers, and is attached to, the ends of the corpora cavernosa. The projecting margin of its base is named the *corona glandis,* and the constriction behind the latter is known as the *neck of the glans.* The terminal part of the urethra runs through the glans penis, and ends in a vertical slit on its apex.

The skin covering the penis is remarkable for its thinness, its dark colour, its looseness of connexion with the fibrous envelope of the organ, and its absence of adipose tissue. At the root of the penis it is continuous with the skin over the pubes, scrotum, and perinæum. At the neck of the glans penis it is folded upon itself to form the *prepuce* or *foreskin,* which overlaps the glans for a variable distance. The internal layer of the prepuce is confluent along the line of the neck with the thin skin which covers, and adheres firmly to, the glans, and is continuous with the mucous membrane of the urethra at the external urethral orifice. On the under surface of the glans penis a small median fold passes from the deep surface of the prepuce to a point on the glans immediately behind the external urethral orifice; this median fold is named the *frenulum* of the prepuce. The prepuce is separated from the glans penis by a potential sac—the *preputial sac*—which presents two shallow fossæ, one on either side of the frenulum. On the corona and neck of the glans there are numerous small *preputial glands*; these secrete a sebaceous material named the *smegma præputii,* which possesses a very peculiar odour.

Structure of the penis.—From the internal surface of the fibrous envelope of the corpora cavernosa penis, as well as from the sides of the septum, numerous *trabeculæ* arise, and cross the corpora cavernosa in all directions, subdividing them into a number of *cavernous spaces,* and giving the entire structure a spongy appearance (fig. 1180). These trabeculæ consist of white fibrous tissue, elastic fibres and plain muscular fibres (fig. 1181), and in them are contained numerous arteries and nerves. The cavernous spaces are filled with blood, and are lined by a layer of flattened cells similar to the endothelial lining of veins.

The fibrous envelope of the corpus cavernosum urethræ is thinner, whiter in colour, and more elastic than that of the corpora cavernosa penis. The trabeculæ are more delicate, and the meshes between them are smaller than in the corpora cavernosa penis. The envelope of the corpus cavernosum urethræ is formed partly of unstriped muscular fibres, and a layer of the same tissue surrounds the canal of the urethra.

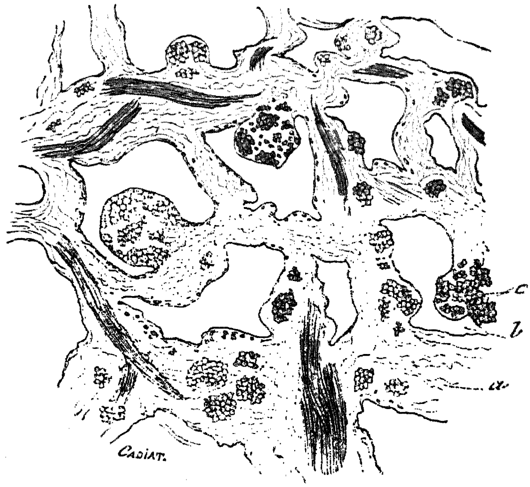
Vessels and Nerves.—The arteries bringing the blood to the cavernous spaces are the deep arteries of the penis, and branches from the dorsal arteries of the penis, which perforate the fibrous capsule, along the upper surface, especially near the front part of the organ. On entering the cavernous structure the arteries divide into branches, which are supported and enclosed by the trabeculæ. Some of these arteries end in a capillary network, the branches of which open directly into the cavernous spaces; others assume a tendril-like appearance, and form convoluted and somewhat dilated vessels, named *helicine arteries.* They open into the cavernous spaces, and from them small capillary branches go to supply the trabecular structure. They are most abundant in the posterior parts of the corpora cavernosa.

The blood from the cavernous spaces is returned by a series of vessels, some of which emerge from the base of the glans penis and converge on the dorsum of the penis to form the deep dorsal vein; others pass out on the upper surface of the corpora cavernosa and join the same vein; some emerge from the under surface of the corpora cavernosa penis and, receiving branches from the corpus cavernosum urethræ, wind round the sides of the penis to end in the deep dorsal vein; but many pass out at the root of the penis and join the prostatic plexus.

The *nerves* are derived from the second, third and fourth sacral nerves, through the pudendal nerve and the pelvic plexuses. On the glans penis and the urethral bulb some filaments of the cutaneous nerves have Pacinian bodies connected with them, and many of them end in peculiar end-bulbs (p. 1048).

Applied Anatomy.—The penis occasionally requires removal for malignant disease. Removal of the antescrotal portion is usually all that is necessary, but sometimes it is requisite to remove the whole organ from its attachment to the pubic and ischial rami. The former operation is performed by cutting through the corpora cavernosa penis from the dorsum, and then separating the corpus cavernosum urethræ from them, dividing it at a level nearer the glans penis. The mucous membrane of the urethra is then slit up, and the edges of the flap attached to the external skin, in order to prevent contraction of the orifice, which might otherwise take place. The vessels which require to be ligatured are the deep and the dorsal arteries of the penis, and the artery of the septum. When the entire organ requires removal, the patient is placed in the lithotomy position, and an incision is made through the skin and subcutaneous tissue round the root of the penis, and carried down through the median line of the scrotum as far as the perinæum. The halves of the scrotum are then separated from each other, and, a catheter having been introduced into the bladder as a guide, the corpus cavernosum urethræ below the urogenital diaphragm is separated from the corpora cavernosa penis and divided, the catheter having been withdrawn. The suspensory ligament is now severed and the crura separated from the bone with a periosteum scraper. The portion of the urethra, which has not been removed, is attached to the skin at the posterior extremity of the incision in the perinæum. The remainder of the wound is closed, free drainage being provided for.

Fig. 1181.—A section through the corpus cavernosum penis in the non-distended condition. (Cadiat.)



a. Trabeculæ of connective tissue, with many elastic fibres and bundles of plain muscular tissue, some of which are cut across (*c*). *b*. Blood-sinuses.

The Prostate

The **prostate** (fig. 1176) is a firm, partly glandular and partly muscular body, surrounding the commencement of the urethra. It is situated in the pelvic cavity, behind the lower part of the symphysis pubis and the superior fascia of the urogenital diaphragm, and in front of the rectum. It is about the size of a chestnut and somewhat conical in shape, and presents for examination a base, an apex, a posterior, an anterior, and two lateral surfaces.

The *base* is directed upwards, and, for the greater part of its extent, is directly continuous with the wall of the urinary bladder: the urethra enters it nearer its anterior than its posterior border.

The *apex* is directed downwards, and is in contact with the superior fascia of the urogenital diaphragm.

The *posterior surface* is flattened from side to side and slightly convex from above downwards; it is separated by its sheath and some loose connective tissue from the rectum, and is distant about 4 cm. from the anus. Near its upper border is a depression through which the two ejaculatory ducts enter the prostate. This depression serves to divide the posterior surface into a lower larger and an upper smaller part. The upper smaller part constitutes the *middle lobe* of the prostate and intervenes between the ejaculatory ducts and the urethra; it varies greatly in size, and in some cases is destitute of glandular tissue. The lower larger portion sometimes presents a shallow median furrow, which imperfectly separates it into *right* and *left lateral lobes*; these form the main mass of the gland and are directly continuous with each other behind the urethra; they are connected in front of the urethra by a band which is named the *isthmus*; the latter consists of fibromuscular tissue and is devoid of glandular substance.

The *anterior surface* is narrow and convex from side to side. It lies about

2 cm. behind the pubic symphysis, from which it is separated by a plexus of veins and a quantity of loose fatty tissue. It is connected to the pubic bones by the puboprostatic ligaments. The urethra emerges from this surface a little above and in front of the apex of the prostate.

The *lateral surfaces* are prominent, and are covered by the anterior portions of the Levatores ani, which are, however, separated from the gland by a plexus of veins.

The prostate measures about 4 cm. transversely at the base, about 2 cm. in its anteroposterior, and 3 cm. in its vertical, diameter. Its weight is about 8 gm. It is invested by a fibrous sheath derived from the pelvic fascia. This sheath is continuous above with the rectovesical fascia which ensheathes the vesiculæ seminales and ductus deferentes, below with the superior fascia of the urogenital diaphragm, and in front with the puboprostatic ligaments. These ligaments are two thickened bands of pelvic fascia which pass backwards, one on each side of the middle line, from the pubic bones to the front of the prostate; between the ligaments is a median depression the floor of which is formed by a thinner part of the fascia.* The anterior portions of the Levatores ani pass backwards from the os pubis and embrace the sides of the prostate; from the support they afford to the prostate they are named the *Levatores prostatæ*.

The prostate is perforated by the urethra and the ejaculatory ducts and contains the prostatic utricle. The urethra usually lies along the junction of its anterior with its middle one-third. The ducts pass obliquely downwards and forwards through the posterior part of the prostate, and open into the prostatic portion of the urethra (p. 1218).

Structure (fig. 1182).—The prostate is enveloped by a thin but firm capsule, distinct from the sheath derived from the pelvic fascia, and separated from it by a plexus of veins. This capsule is firmly adherent to the prostate and is structurally continuous with the stroma of the gland, being composed of the same tissues, viz. non-striped muscle and fibrous tissue. The substance of the prostate is of a pale reddish-grey colour, of great density, and not easily torn. It consists of glandular substance and muscular tissue.

The *muscular tissue* constitutes the proper stroma of the prostate; the connective tissue being very scanty, and merely forming, between the muscular fibres, thin trabeculæ in which the vessels and nerves of the gland ramify. The muscular tissue is arranged as follows: immediately beneath the capsule is a dense layer, which forms an investing sheath for the gland; around the prostatic part of the urethra is a dense layer of circular fibres, continuous above with the internal layer of the muscular coat of the bladder, and blending below with the fibres surrounding the membranous portion of the urethra; between these two layers are strong bands of muscular tissue which decussate freely, and form meshes in which the glandular structure of the organ is imbedded. In that part of the gland which is situated in front of the urethra the muscular tissue is especially dense, and there is here little or no glandular tissue; while in that part which is behind the urethra the muscular tissue presents a wide-meshed structure, which is densest at the base of the gland—that is, near the bladder—becoming looser and more sponge-like towards the apex.

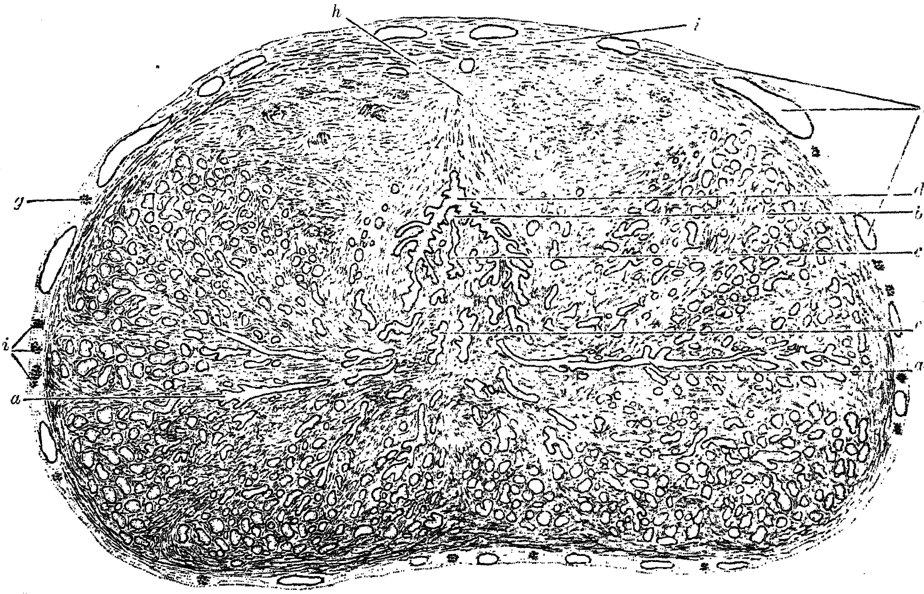
The *glandular substance* is composed of numerous follicles the lining of which frequently shows papillary elevations. The follicles open into elongated canals which join to form from twelve to twenty small excretory ducts. They are connected together by areolar tissue, supported by prolongations from the fibrous capsule and muscular stroma, and enclosed in a delicate capillary plexus. The epithelium which lines the canals and the terminal vesicles is of the columnar variety. The prostatic ducts open into the floor of the prostatic portion of the urethra, and are lined by two layers of epithelium, the inner layer consisting of columnar and the outer of small cubical cells. Small colloid masses, known as amyloid bodies, are often found in the gland tubes.

* G. Elliot Smith (*Journal of Anatomy*, vol. xlii.) pointed out that in a mesial section through the pelvis of a male fœtus of the fourth month the rectovesical excavation or recess of the peritoneum is seen to be very much deeper than it is in the adult; it extends downwards on the posterior surface of the prostate and is attached there to the upper extremity of the perinæal body.

The two layers of this recess become loosely attached to one another and their serous covering disappears, the two layers of peritoneum being transformed into or replaced by a double sheet of fibrous tissue, mixed with some unstriped muscle. This sheet he names the *rectovesical septum* and states that it is almost identical with the 'rectovesical fascia,' except that its lateral borders are either quite free or attached to the sheath of the vesical plexuses. The rectovesical septum is a triangular sheet, the superior border of which is attached to the peritoneum, while its three angles are placed respectively at the outer extremities of the vesiculæ seminales and the lower edge of the prostate. The posterior part of the capsule of the prostate is formed mainly by the rectovesical septum.

Vessels and Nerves.—The *arteries* supplying the prostate are derived from the internal pudendal, inferior vesical, and middle hæmorrhoidal arteries. Its *veins* form a plexus around the sides and base of the gland; they receive in front the dorsal vein of the penis, and end in the hypogastric veins. The *lymphatics* are described on p. 772. The *nerves* are derived from the pelvic plexus.

Fig. 1182.—A transverse section through a normal prostate, opposite the middle of the urethral crest. From a subject aged nineteen years. (Taylor.)



a. Longitudinal section of ducts leading from the lobules of the glands. *b.* Urethral crest. *c.* Prostatic utricle. *d.* Urethra. *e.* Ejaculatory ducts. *f.* Arteries, veins, and venous sinuses in sheath of prostate. *g.* Nerve-trunks in sheath. *h.* Point of origin of fibromuscular bands encircling urethra. *i.* Zone of striated voluntary muscle on superior surface.

Applied Anatomy.—By means of the finger introduced into the rectum, the surgeon detects enlargement or other disease of the prostate; he can feel the apex of the gland, which is the guide to Cock's operation for stricture; he is enabled also by the same means to direct the point of a catheter, when its introduction is attended with difficulty either from injury or disease of the membranous or prostatic portions of the urethra. When the finger is introduced into the bowel, the surgeon may, in some cases, especially in boys, learn the position, as well as the size, of a calculus in the bladder. If, as is not infrequently the case, the calculus be lodged behind an enlarged prostate, it may be displaced from its position by pressing it upwards towards the fundus of the bladder from the rectum. The prostate is occasionally the seat of suppuration, due to either gonorrhœa or tuberculous disease. The gland is enveloped in a dense unyielding capsule, which determines the course of the abscess, and also explains the great pain which is present in the acute form of the disease. The abscess most frequently bursts into the urethra, the direction in which there is least resistance, but may burst into the rectum, or more rarely in the perinæum. In advanced life the prostate sometimes becomes considerably enlarged and projects into the bladder so as to impede the passage of the urine. According to Messer's researches, conducted at Greenwich Hospital, it would seem that such obstruction exists in 20 per cent. of all men over sixty years of age. In some cases the condition affects principally the lateral lobes, which may undergo considerable enlargement without causing much inconvenience. In other cases it would seem that the middle lobe enlarges most, and even a small enlargement of this lobe may act injuriously, by forming a sort of valve over the internal urethral orifice, preventing the passage of the urine; and the more the patient strains, the more completely will it block the opening into the urethra. In consequence of the enlargement of the prostate, a pouch is formed at the base of the bladder behind the projection, in which urine collects, and from which it cannot be entirely expelled. For this condition *prostatectomy* is sometimes done. The bladder is opened by an incision above the symphysis pubis, the mucous membrane of the post-prostatic pouch is scratched through, and the finger is then introduced into the space between the true capsule of the prostate and outer capsule formed by the pelvic fascia. Separation in this plane is then carried out below and laterally until the apex of the gland is reached. The whole of the work is done with the finger, which is gradually swept round the sides until the anterior surface is reached and

freed. The gland is then, by traction, displaced into the bladder and removed, usually carrying with it the greater portion of the mucous membrane of the prostatic urethra. Hæmorrhage, which may be considerable at times, is checked by hot irrigations, and the bladder is temporarily drained. Very satisfactory results have followed this operation.

The prostate can be reached from the perinæum, and in some cases the enlarged gland has been removed by this route, but the perinæal approach is not usually employed except in the case of abscess of or about the gland.

The Bulbo-urethral Glands

The **bulbo-urethral glands** (Cowper's glands) are two small, rounded and somewhat lobulated bodies, of a yellow colour. Each is about the size of a pea, and is placed lateral to the membranous portion of the urethra, between the two layers of the fascia of the urogenital diaphragm. They lie above the urethral bulb, and are enclosed by the transverse fibres of the Sphincter urethræ membranaceæ. They gradually diminish in size as age advances.

The excretory duct of each gland is nearly 3 cm. long; it passes obliquely forwards beneath the mucous membrane, and opens by a minute orifice on the floor of the cavernous portion of the urethra about 2·5 cm. in front of the urogenital diaphragm.

Structure—Each gland is made up of several lobules which are held together by a fibrous investment. Each lobule consists of a number of acini, lined by columnar epithelial cells.

THE FEMALE GENITAL ORGANS

The female genital organs consist of an internal and an external group. The *internal organs* are situated within the pelvis, and consist of the ovaries, the uterine (Fallopian) tubes, the uterus, and the vagina. The *external organs* are placed below and in front of the pubic arch. They comprise the mons pubis, the labia majora et minora pudendi, the clitoris, the bulbus vestibuli, and the greater vestibular glands.

The Ovaries

The **ovaries**, two in number, are homologous with the testes in the male. They are situated one on either side of the uterus in relation to the lateral wall of the pelvis, and attached to the back of the broad ligament of the uterus behind and below the uterine tube (fig. 1183). They are of a greyish-pink colour, and present either a smooth or a puckered uneven surface; each is about 3 cm. long, 1·5 cm. wide, and about 10 mm. thick. In the erect posture the long axis of the ovary is vertical. Each ovary presents a lateral and a medial surface, a tubal and a uterine extremity, and a mesovarian and a free border. The ovary lies in a depression, named the *ovarian fossa*, on the lateral wall of the pelvis; this fossa is bounded in front by the obliterated hypogastric artery, and behind by the ureter and the uterine artery. The exact position of the ovary has been the subject of considerable difference of opinion, and the description here given applies to that of the nulliparous woman; the ovary is displaced during the first pregnancy, and probably never again returns to its original position. The *tubal extremity* (extremitas tubaria) is near the external iliac vein; to it are attached the ovarian fimbria of the uterine tube and a fold of peritoneum, the *suspensory ligament of the ovary*, which passes upwards over the iliac vessels and contains the ovarian vessels and nerves. The *uterine extremity* (extremitas uterina) is directed downwards towards the pelvic floor; it is usually narrower than the tubal extremity, and is attached to the lateral angle of the uterus, immediately behind and below the uterine tube, by a rounded cord termed the *ligament of the ovary*, which lies within the broad ligament and contains some non-striped muscular fibres. The *lateral surface* is in contact with the parietal peritoneum, which lines the ovarian fossa and separates the ovary from the subperitoneal connective tissue and the obturator vessels; the *medial surface* is to a large extent covered by the uterine tube. The *mesovarian border* is straight and is directed towards the obliterated hypogastric artery; it is attached to the back of the broad ligament by a short fold named the *mesovarium*. Between the two layers of this fold the

between the lower ribs and the ilium when the body is violently bent forwards. This is followed by a little transient hæmaturia, which, however, speedily passes off.

The loose cellular tissue around the kidney may be the seat of suppuration, constituting *perinephric abscess*. This may be due to injury, or to disease of the kidney itself, or to extension of inflammation from neighbouring parts. The abscess tends to point externally in the groin or loin.

Tumours of the kidney may be recognised by their position: by the resonant colon lying in front of them; and by their rounded outline not presenting a notched anterior margin like the spleen, with which they are most likely to be confounded. The *hypernephroma*, a tumour arising from suprarenal 'rests' or inclusions in the cortex or medulla of the kidney, is not infrequent. When occurring in children it is often associated with precocious growth of the body generally and of the hair and sexual organs in particular. Arising, as it often does, in the kidney, a hypernephroma is indistinguishable from a true renal tumour so far as the physical signs and symptoms go; it is really, however, a tumour of the suprarenal gland substance.

The examination of the kidney should be bimanual; that is to say, one hand should be placed in the flank and firm pressure made forwards, while the other hand is buried in the abdominal wall, over the situation of the organ. Manipulation of the kidney frequently produces a peculiar sickening sensation, sometimes with faintness.

The kidney may require exposure for exploration or the evacuation of pus (*nephrotomy*); it may be incised for the removal of stone (*nephrolithotomy*); it may be sutured when movable or floating (*nephropexy*); or it may be removed (*nephrectomy*). It may be exposed either by a lumbar or an abdominal incision; except in cases of very large tumours, a lumbar incision is best, as it has the advantages of not opening the peritoneum, and of affording admirable drainage. An oblique incision should be made, starting at the lateral border of the Sacrospinalis, 1 cm. below the last rib and directed downwards and forwards towards a point 2·5 cm. in front of the anterior superior spine of the ilium. The structures divided are the skin, the superficial fascia with the cutaneous nerves, the deep fascia, the posterior border of the Obliquus externus abdominis, and the outer border of the Latissimus dorsi; the Obliquus internus and the posterior aponeurosis of the Transversus abdominis; the lateral border of the Quadratus lumborum; the deep layer of the lumbodorsal fascia and the transversalis fascia. The fatty tissue around the kidney is now exposed to view, and must be separated by the fingers, or a director, in order to reach the kidney. The operations of nephrolithotomy, for the removal of calculi from the kidney, and nephrotomy, or incision of the kidney for abscess, &c., are generally performed by the lumbar incision. This route is also generally chosen for nephrectomy, especially if the organ is thought to contain pus. The abdominal operation is best performed by an incision through the lateral part of the Rectus abdominis on the side of the kidney to be removed; the kidney is then reached from the lateral side of the colon, ascending or descending as the case may be, and thus the vessels of the colon are not interfered with. The incision commencing just below the costal arch is made of varying length, according to the size of the kidney. The abdominal cavity having been opened, the intestines are drawn medialwards and the peritoneum covering the kidney to the lateral side of the colon is incised, so that the fingers can be introduced behind the peritoneum. The kidney must now be enucleated, and the vessels firmly ligatured and divided, the ureter being tied separately. The particular advantage of the abdominal operation is that the condition of the other kidney can be ascertained by manual examination, before the removal of the diseased kidney is finally decided upon; and, further, involvement of neighbouring structures by a new growth, rendering removal impossible, can only be discovered by the abdominal route.

Nephropexy is the name given to the operation for fixing a movable kidney. The kidney is reached by the lumbar incision, and is freely separated from its perinephric capsule. Sutures are then passed through the true capsule of the organ and are brought out above the upper end of the wound. When these sutures are tied, the kidney is tightly anchored in position; at the same time a flap of the true capsule can be separated from the parenchyma of the kidney and passed around the last rib and sutured down again, so as to form a sling for the kidney from the rib.

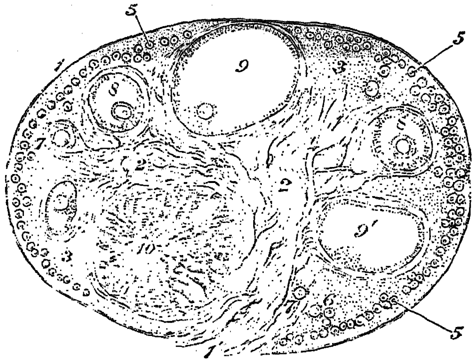
The Ureters

The **ureters** are the two tubes which convey the urine from the kidneys to the urinary bladder. Each measures from 25 cm. to 30 cm. in length, and is a thick-walled, narrow, cylindrical tube which is directly continuous with the tapering lower end of the renal pelvis. It runs downwards and medialwards in front of the Psoas major and, entering the pelvic cavity, finally opens into the fundus of the urinary bladder.

The *abdominal part* lies behind the peritoneum on the medial portion of the Psoas major, and is crossed obliquely by the testicular vessels. It enters the pelvic cavity by crossing either the end of the common, or the beginning of the external, iliac vessels.

Vesicular ovarian (*Graafian*) *follicles.*—Upon making a section through an ovary, numerous vesicles of various sizes are seen; they are the follicles, or ovisacs containing the ova. Immediately beneath the tunica albuginea is a layer of stroma, called the *cortical layer*, characterised by the presence of a large number of ova in an early stage of development. At this stage each ovum is a spherical cell, and is surrounded by a single layer of smaller, cubical cells. These primitive follicles are numerous in the ovary of the child.

FIG. 1185.—A section through the ovary. (After Schrön.)

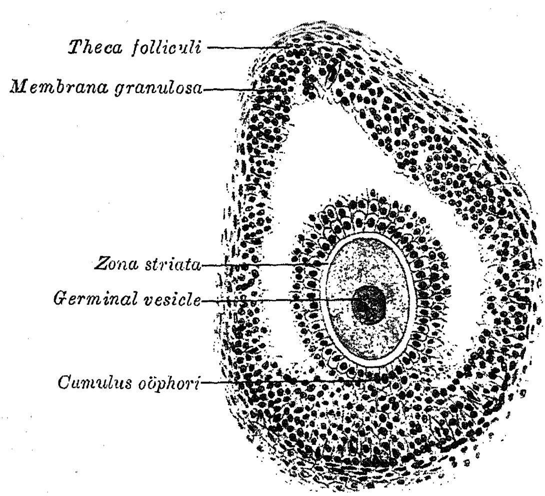


1. Outer covering. 1'. Attached border. 2. Central stroma. 3. Peripheral stroma. 4. Blood-vessels. 5. Vesicular follicles in their earliest stage. 6, 7, 8. More advanced follicles. 9. An almost mature follicle. 9'. Follicle from which the ovum has escaped. 10. Corpus luteum.

After puberty some of these primitive ovarian follicles increase in size; the cells investing the ovum multiply, and later a cavity, named the *antrum folliculi*, appears between the cells thus formed. This cavity is filled with *liquor folliculi*, a transparent, albuminous fluid which nourishes and protects the ovum. The liquor folliculi splits the investing cells into two strata, an outer named the *stratum granulosum* and an inner, the *cumulus oöphori*; the latter surrounds the ovum * and is attached at one spot to the stratum granulosum (fig. 1186). Thomson † is of opinion that the cumulus may be attached to the stratum granulosum at any part of the circumference of the follicle. In the earlier stages of the development of the follicle the stratum granulosum is made up of several layers of cubical cells, but in the matured follicle it consists of a single layer, and in some instances this may disappear.

Scattered amongst the cells of the cumulus oöphori and stratum granulosum are certain structures known as the *bodies of Call and Exner*, the cells surrounding which are radially arranged; in the advanced stages of the growth of the follicle these bodies are only found in the cumulus. Each consists of a more or less homogeneous mass of protoplasm, which, in its reactions to certain stains, resembles the coagulated liquor folliculi. These bodies become vacuolated, and tend to break down, and it is therefore probable that the liquor folliculi is formed, in the first instance, by their dissolution.

FIG. 1186.—A section through an ovarian follicle of a cat. × 50.



A fully developed or 'ripe' ovarian follicle is about 5 mm. in diameter (Thomson, loc. cit.) and is surrounded by a capsule (*theca folliculi*) derived from the ovarian stroma, and composed of an internal and an external tunic. The *tunica interna* consists of loosely-arranged, round or spindle-shaped cells, and is pervaded by a capillary plexus. The vascularity of this tunic increases as the follicle matures, and the capillary vessels then extend between the cells of the attached part of the cumulus. Between the tunica interna and the stratum granulosum which lines it, there is a thin *external limiting membrane* (basal membrane). The *tunica externa* consists of firmer and less vascular tissue than the tunica interna, and contains a considerable quantity of non-striped muscular fibres.

The mature follicle approaches, and ultimately bursts on, the surface of the ovary, and the escaped ovum, surrounded by the cells of the cumulus oöphori, is grasped by the

* The ovum is described on pp. 40 to 42.

† Consult, in this connexion, an article by Arthur Thomson on "The ripe human Graafian follicle," *Journal of Anatomy*, vol. liv.

fimbriated end of the uterine tube, and is conveyed along this tube to the cavity of the uterus. The rupture of the follicle is probably brought about by the contraction of the non-striped muscular fibres of the tunica externa.

Robinson * has investigated the formation, rupture, and closure of the ovarian follicles in ferrets, and has shown that in these animals a fluid, named by him the *secondary liquor folliculi*, appears between the cells of the cumulus oöphori and takes part in the final distension of the follicle which precedes rupture.

The maturation of the follicles and ova continues uninterruptedly from puberty to the end of the reproductive period of woman's life, while their formation commences before birth.

Corpus luteum.—After the discharge of the ovum a series of changes occurs within the Graafian follicle which result in the formation of a structure named the *corpus luteum.* When fully developed this consists of large cells containing yellow pigment (*luteal cells*) separated from one another by delicate trabeculæ of vascular connective tissue which is aggregated to form a mass in the centre of the follicle devoid of luteal cells. Opinion is divided as to what is the source of the luteal cells. Many regard them as being derived from the tunica interna, a view which is supported by the fact that the stratum granulosum may be separated from the external limiting membrane before the ovarian follicle bursts. Others maintain that they are derived from the cells of the stratum granulosum, which undergo great hypertrophy, and, in the early stages of the formation of the corpus luteum, show signs of mitosis. The connective tissue trabeculæ are derived from the sheath of the follicle.

If the discharged ovum be not fertilized the corpus luteum quickly degenerates, and within two months is reduced to a small cicatrix, but if the ovum be fertilized the corpus luteum increases in size and, by the middle of pregnancy, may measure about 2·5 cm. in diameter. During the later months of pregnancy the luteal cells lose their colour, and the size of the corpus luteum diminishes, so that by the end of pregnancy its diameter is reduced to about 1 cm.†

Vessels and Nerves.—The *arteries* of the ovaries and uterine tubes are the ovarian arteries from the aorta. Each anastomoses in the mesosalpinx with the uterine artery; it gives some branches to the uterine tube, and others which traverse the mesovarium and enter the hilum of the ovary. The *veins* emerge from the hilum in the form of a plexus, the *pampiniform plexus*; the ovarian vein is formed from this plexus, and leaves the pelvis in company with the artery. The *lymphatics* are described on p. 774. The *nerves* are derived from the hypogastric or pelvic plexus, and from the ovarian plexus, the uterine tube receiving a branch from one of the uterine nerves.

Epoöphoron (figs. 1183, 1184).—The epoöphoron or organ of Rosenmüller lies in the lateral part of the mesosalpinx between the ovary and the uterine tube, and consists of a few short tubules (*ductuli transversi*) which converge towards the ovary while their opposite ends open into a rudimentary duct, the *ductus longitudinalis epoöphori* (duct of Gärtner), which runs in the broad ligament of the uterus, parallel with the lateral part of the uterine tube.

In a small proportion of subjects Gärtner's duct can be followed alongside the uterus to near the level of the internal orifice. Here it pierces the muscular wall of the uterus and descends in the cervix uteri, gradually approaching the mucous membrane, without however quite reaching it. The duct then runs downwards in the lateral wall of the vagina and ends at, or close to, the free margin of the hymen.

Paroöphoron.—The paroöphoron consists of a few scattered rudimentary tubules, best seen in the child, situated in the broad ligament between the epoöphoron and the uterus.

The ductuli transversi of the epoöphoron and the tubules of the paroöphoron are remnants of the tubules of the Wolffian body or mesonephros; the ductus longitudinalis epoöphori is a persistent portion of the Wolffian duct.

Applied Anatomy.—The inflammations which affect the ovary are merely an extension of those from the uterine tube. Ovarian new formations are of common occurrence, and are either solid or cystic; the former being the less common. The '*ovarian cysts*' in the majority of cases are cystadenomata which may spring from the ovarian follicles and assume enormous dimensions; in rarer instances they arise from the tubules at the hilum of the ovary or those of the epoöphoron; in other instances a clear watery cyst forms between the layers of the broad ligament. An ovarian cyst, once diagnosed, should always be removed, as it is liable to become affected by suppuration, torsion of its pedicle, or other serious complications. The operation for its removal, badly termed *ovariotomy*, consists in opening the abdomen and delivering the cyst through the wound; the pedicle is then clamped with forceps, and the cyst is cut free. The pedicle must be transfixed and securely ligatured by an interlocking ligature, which will not slip off. The pedicle consists of an elongated part of the broad ligament, including the uterine tube and ovarian artery, and a great number of large veins. Ovariotomy for a simple uncomplicated cyst presents no special difficulties, but, in cases where there are old adhesions implicating the small intestine, it may present very great difficulties.

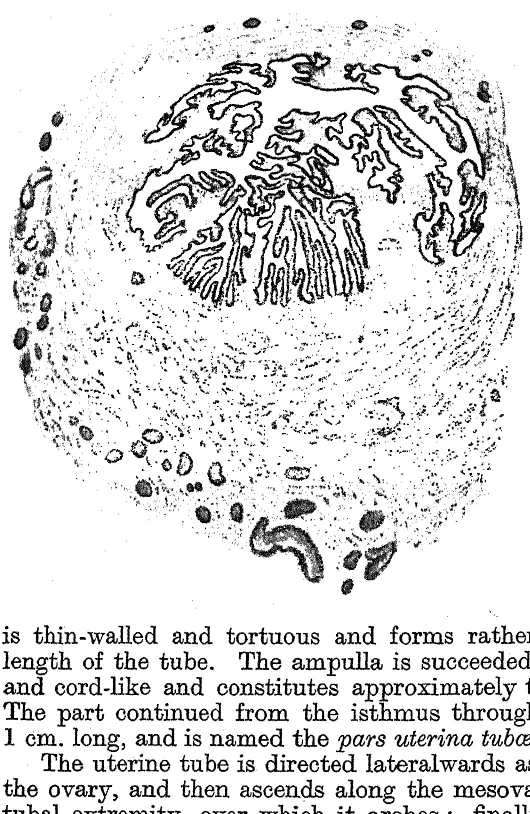
* Arthur Robinson, *Transactions of the Royal Society of Edinburgh,* vol. lii. part ii.

† Consult *The Physiology of Reproduction* by F. H. A. Marshall, 1910.

The Uterine Tubes (figs. 1183, 1188)

The **uterine tubes** (Fallopian tubes), two in number, transmit the ova from the ovaries to the cavity of the uterus and are situated in the upper margins of the broad ligaments of the uterus. Each tube is about 10 cm. long, and one end of it opens into the superior angle of the cavity of the uterus, the other into the peritoneal cavity close to the ovary. The opening into the uterine cavity is very small, and only admits a fine bristle; the opening into the peritoneal cavity is named the *abdominal ostium*, and when its muscular wall is relaxed has a diameter of about 3 mm. The abdominal ostium is situated at the bottom of a trumpet-shaped expansion of the uterine tube, termed the *infundibulum*, the circumference of which is prolonged into a varying number of irregular processes, called *fimbriæ*, and therefore this ostium is sometimes called the *fimbriated end* of the tube. The inner surfaces of the fimbriæ are lined by mucous membrane, and in the larger fimbriæ this exhibits longitudinal folds which are continuous with similar folds in the mucous lining of the infundibulum. One fimbria, longer and more deeply grooved than the others, is attached to the tubal extremity of the ovary, and is named the *ovarian fimbria*. The infundibulum opens into the *ampulla* of the tube, which is thin-walled and tortuous and forms rather more than one-half the entire length of the tube. The ampulla is succeeded by the *isthmus*, which is round and cord-like and constitutes approximately the medial one-third of the tube. The part continued from the isthmus through the wall of the uterus is about 1 cm. long, and is named the *pars uterina tubæ*.

Fig. 1187.—Transverse section of a human uterine tube. Stained with hæmatoxylin and eosin. ×15.



The uterine tube is directed lateralwards as far as the uterine extremity of the ovary, and then ascends along the mesovarian border of the ovary to the tubal extremity, over which it arches; finally it turns downwards and ends in relation to the free border and medial surface of the ovary. In connexion with the fimbriæ of the uterine tube, or with the broad ligament close to them, there are frequently one or more small pedunculated vesicles; these are termed the *appendices vesiculosæ* (hydatids of Morgagni).

Structure (fig. 1187).—The uterine tube consists of three coats: serous, muscular, and mucous. The *external or serous coat* is peritoneal. The *middle or muscular coat* consists of an external longitudinal and an internal circular layer of non-striped muscular fibres continuous with those of the uterus. The *internal or mucous coat* is continuous with the mucous lining of the uterus, and, at the abdominal ostium of the tube, with the peritoneum. It is thrown into longitudinal folds, which in the ampulla are much more extensive than in the isthmus. The lining epithelium is columnar and ciliated. This form of epithelium is also found on the inner surfaces of the fimbriæ; while on the outer or serous surfaces of these processes the epithelium gradually merges into the endothelium of the peritoneum.

Applied Anatomy.—The majority of the diseases of the uterine tube are due to infections which have spread by way of the vagina and uterus, and the disease often does not stop at the uterine tube, but passes on to the peritoneum, giving rise to acute general peritonitis, or a localised condition termed *perimetritis* that may be acute or chronic.

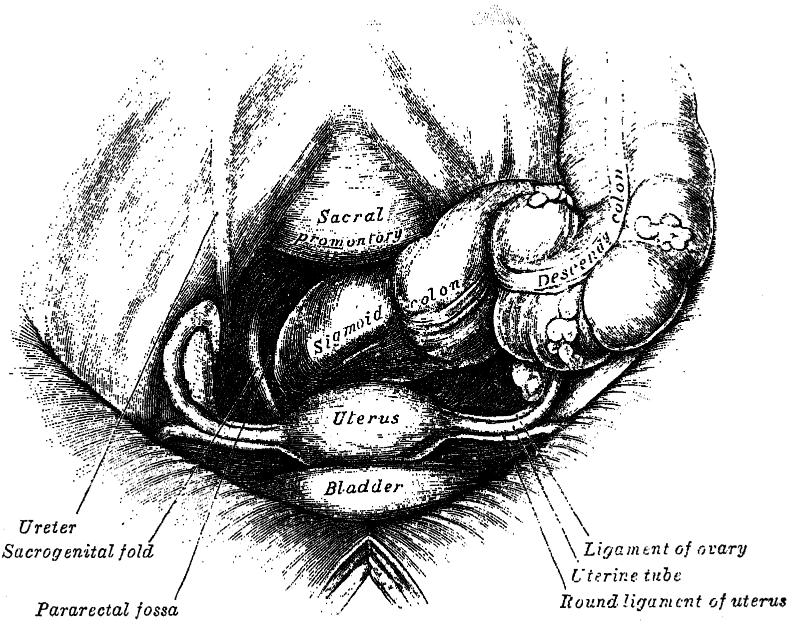
Perimetritis is often followed by various painful conditions, which are due to the peritoneal adhesions resulting from the inflammation of the serous membrane, and which persist throughout life. Tubal inflammation (*salpingitis*) is usually the result of an infection either by the gonococcus, or by septic organisms implanted at the time of labour or abortion. In many cases the fimbriated ends of the tubes become closed by adhesions, pus collects in the tubes, and a *pyosalpinx* results.

Fertilisation of the ovum (p. 46) is believed to occur in the uterine tube, and the fertilised ovum is then normally passed on into the uterus; the ovum, however, may adhere to and undergo development in the tube, giving rise to the commonest variety of *ectopic gestation*. In such cases the amnion and chorion are formed, but a true decidua is never present; and the gestation usually ends by extrusion of the ovum through the abdominal ostium, although it is not uncommon for the tube to rupture into the peritoneal cavity, this being accompanied by severe hæmorrhage, and needing surgical interference.

The Uterus (figs. 1183, 1188, 1189)

The **uterus**, or **womb**, is a hollow, thick-walled, muscular organ situated in the pelvic cavity between the urinary bladder in front and the rectum behind. Into its upper part the uterine tubes open, one on either side, while below, its

Fig. 1188.—The female pelvis and its contents. Anterosuperior aspect.



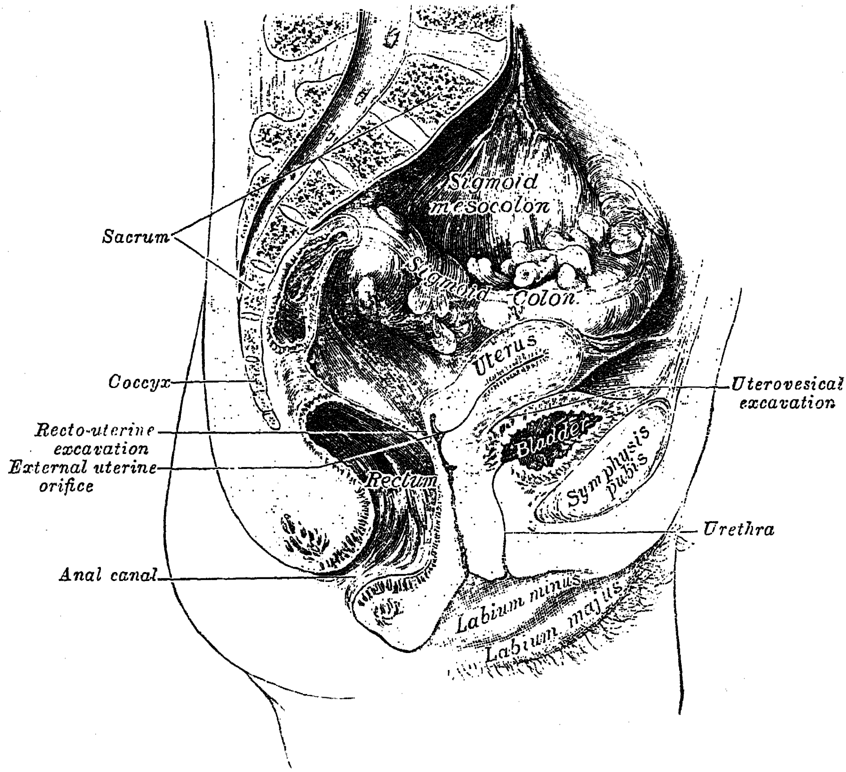
cavity communicates with that of the vagina. When the ova are discharged from the ovaries they are carried to the uterine cavity through the uterine tubes. If an ovum be fertilised it imbeds itself in the uterine wall and is normally retained in the uterus until prenatal development is completed, the uterus undergoing changes in size and structure to accommodate itself to the needs of the growing embryo. After parturition the uterus returns almost to its former condition, but traces of its enlargement remain. For general descriptive purposes the adult virgin uterus is taken as the type form.

In the virgin state the uterus is flattened from before backwards and is pyriform in shape, with the apex directed downwards and backwards. It lies between the bladder below and in front and the sigmoid colon and rectum above and behind, and is completely within the pelvis, its base being below the level of the superior pelvic aperture. Its upper part is suspended by the broad and the round ligaments, while its lower portion is imbedded in the fibrous tissue of the pelvis.

The long axis of the uterus usually lies approximately in the axis of the superior pelvic aperture, but as the organ is freely movable its position varies with the state of distension of the bladder and rectum. Except when much displaced by a distended bladder, it forms a forward angle with the vagina, since the axis of the vagina corresponds to the axes of the cavity and inferior aperture of the pelvis.

The uterus measures about 7·5 cm. in length, 5 cm. in breadth at its upper part, and nearly 2·5 cm. in thickness; it weighs from 30 to 40 gm. It is divisible into two portions. On the surface, a little below the middle, is a slight constriction, known as the *isthmus*, and corresponding to this in the interior is a narrowing of the uterine cavity, the *internal orifice* of the uterus. The portion above the isthmus is termed the *body*, and that below, the *cervix*.

Fig. 1189.—A median sagittal section through the female pelvis.



The part of the body which lies above a plane passing through the points of entrance of the uterine tubes is known as the *fundus*.

Body.—The body gradually narrows from the fundus to the isthmus.

The *vesical or anterior surface* is in apposition with the urinary bladder. It is flattened and covered by peritoneum, which is reflected on to the bladder as the vesico-uterine fold. The recess or pouch between the bladder and the uterus is named the *vesico-uterine excavation*.

The *intestinal or posterior surface* is convex transversely, and is covered by peritoneum, which is continued downwards on the cervix uteri and the upper part of the vagina. It is in relation with the sigmoid colon, from which it is usually separated by some coils of small intestine.

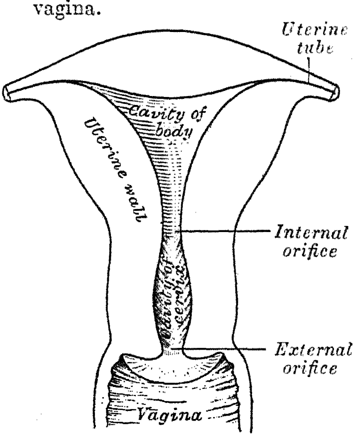
The *fundus* is convex in all directions, and covered by peritoneum continuous with that on the vesical and intestinal surfaces. Some coils of small intestine, and occasionally the distended sigmoid colon rest on it.

The *lateral margins* are slightly convex. At the upper end of each the uterine tube pierces the uterine wall. Below and in front of this point the round ligament of the uterus is fixed; below and behind it the ligament of

the ovary is attached. These three structures lie within a fold of peritoneum, named the broad ligament, which is reflected from the margin of the uterus to the wall of the pelvis.

Cervix.—The cervix is the lower constricted segment of the uterus. It is somewhat conical in shape, with its truncated apex directed downwards and backwards, but is slightly wider in the middle than above or below. Owing to its relationships it is less freely movable than the body, so that its long axis is seldom in the same straight line as that of the body. The long axis of the uterus as a whole presents the form of a curved line with its concavity forwards, or in extreme cases there may be an angular bend at the region of the isthmus uteri.

FIG. 1190.—The posterior half of the uterus and upper part of the vagina.



The cervix projects through the anterior wall of the vagina, which divides it into an upper, supravaginal portion, and a lower, vaginal portion.

The *supravaginal portion* is separated *in front* from the bladder by cellular tissue (*parametrium*), which extends also on to the sides of the cervix, and lateralwards between the layers of the broad ligaments. The uterine arteries reach the margins of the cervix in this fibrous tissue, while on either side the ureter runs downwards and forwards in it at a distance of about 2 cm. from the cervix. *Posteriorly*, the supravaginal cervix is covered by peritoneum, which is prolonged below on to the posterior vaginal wall, whence it is reflected to the rectum, forming the recto-uterine excavation (p. 1138). It is in relation with the rectum, from which it may be separated by coils of small intestine.

The *vaginal portion* of the cervix projects into the anterior wall of the vagina between the vaginal fornices (p. 1237). On its projecting rounded extremity is a small, depressed, somewhat circular aperture, the *external orifice of the uterus*, through which the cavity of the cervix communicates with that of the vagina. The external orifice is bounded by two lips, an anterior and a posterior, of which the anterior is the shorter and thicker, although, on account of the slope of the cervix, it projects lower than the posterior. Normally both lips are in contact with the posterior vaginal wall.

Interior of the uterus (fig. 1190).—The cavity of the uterus is small in comparison with the size of the organ.

The **cavity of the body** is a mere slit, flattened from before backwards. It is triangular in shape, the base being formed by the internal surface of the fundus between the orifices of the uterine tubes, the apex by the internal orifice of the uterus; through this orifice the cavity of the body communicates with the canal of the cervix.

The **canal of the cervix** is somewhat fusiform, flattened from before backwards, and broader at the middle than at the ends. It communicates above, through the internal orifice, with the cavity of the body, and below, through the external orifice, with the vaginal cavity. The wall of the canal presents an anterior and a posterior longitudinal ridge, from each of which a number of small oblique columns, the *palmate folds*, proceed, giving the appearance of branches from the stem of a tree; to this arrangement the name *arbor vitæ uteri* is applied. The folds on the two walls are not opposed, but fit between one another so as to close the cervical canal.

The total length of the uterine cavity from the external orifice to the fundus is about 6 cm.

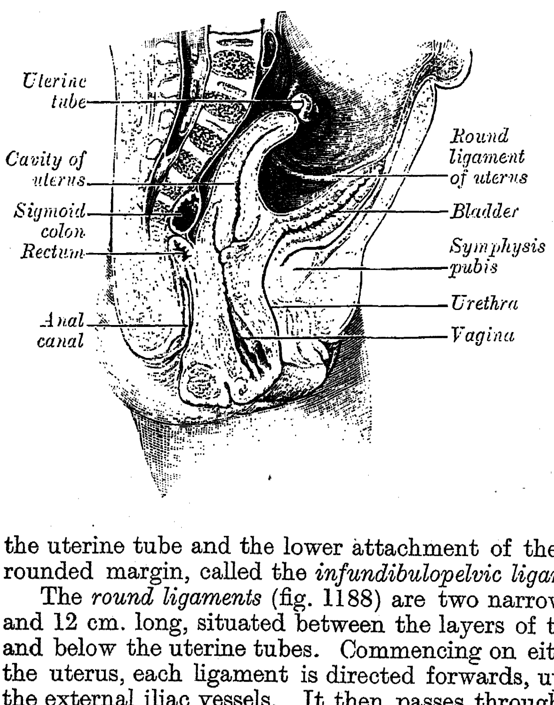
Ligaments.—The ligaments of the uterus are eight in number: an anterior; a posterior; two lateral or broad; two uterosacral; and two round.

The *anterior ligament* consists of the vesico-uterine fold of peritoneum, which is reflected on to the bladder from the front of the uterus, at the junction of the cervix and body.

The *posterior ligament* consists of the rectovaginal fold of peritoneum, which is reflected from the back of the posterior fornix of the vagina on to the front of the rectum. It forms the bottom of a deep pouch called the *recto-uterine excavation* (pouch of Douglas), which is bounded in front by the posterior wall of the body of the uterus, the supravaginal portion of the cervix uteri, and the posterior fornix of the vagina; behind, by the rectum; and laterally by two crescentic folds of peritoneum which pass backwards from the cervix uteri, one on either side of the rectum to the posterior wall of the pelvis. These folds are named the *sacrogenital or recto-uterine folds.* They contain a considerable amount of fibrous tissue and non-striped muscular fibres which are attached to the front of the sacrum and constitute the *uterosacral ligaments.*

The *two lateral or broad ligaments* (fig. 1183) pass from the sides of the uterus to the lateral walls of the pelvis. Together with the uterus they form a septum across the female pelvis, dividing that cavity into two portions. The anterior part contains the bladder; the posterior part, the rectum, and in certain conditions some coils of the small intestine. Between the two layers of each broad ligament are: (1) the uterine tube; (2) the round ligament of the uterus; (3) the ovary and its ligament; (4) the epoöphoron and paroöphoron; (5) connective tissue; (6) unstriped muscular fibres; and (7) blood-vessels and nerves. The portion of the broad ligament which stretches from the uterine tube to the level of the ovary is named the *mesosalpinx.* Between the fimbriated extremity of the uterine tube and the lower attachment of the broad ligament is a concave rounded margin, called the *infundibulopelvic ligament.*

FIG. 1191.—A sagittal section through the pelvis of a new-born female child. Some coils of the small intestine which intervened between the uterus and the bladder have been removed.



The *round ligaments* (fig. 1188) are two narrow, flat bands between 10 cm. and 12 cm. long, situated between the layers of the broad ligament in front of and below the uterine tubes. Commencing on either side at the lateral angle of the uterus, each ligament is directed forwards, upwards, and lateralwards over the external iliac vessels. It then passes through the abdominal inguinal ring and along the inguinal canal to the labium majus, in which it is lost. The round ligaments consist principally of muscular tissue prolonged from the uterus, but also contain some areolar tissue, with blood-vessels, lymphatics, and nerves, enclosed in a duplicature of peritoneum, which, in the fœtus, is prolonged in the form of a tubular process (canal of Nuck) for a short distance into the inguinal canal. The canal of Nuck is generally obliterated in the adult, but sometimes remains pervious even in advanced life. It is analogous to the saccus vaginalis which precedes the descent of the testis.

In addition to the ligaments just described, there is a band named the *ligamentum transversale colli* (Mackenrodt) on either side of the cervix uteri. It is attached to the side of the cervix uteri and to the vault and lateral fornix of the vagina, and is continuous with the fibrous tissue which surrounds the pelvic blood-vessels.

The form, size, and situation of the uterus vary at different periods of life and under different circumstances.

In the fœtus the uterus projects above the superior aperture of the pelvis (fig. 1191). The cervix is considerably larger than the body.

At puberty the uterus is pyriform in shape, and weighs from 14 to 17 gms. The fundus is just below the level of the superior aperture of the pelvis. The palmate folds are distinct, and extend to the upper part of the cavity.

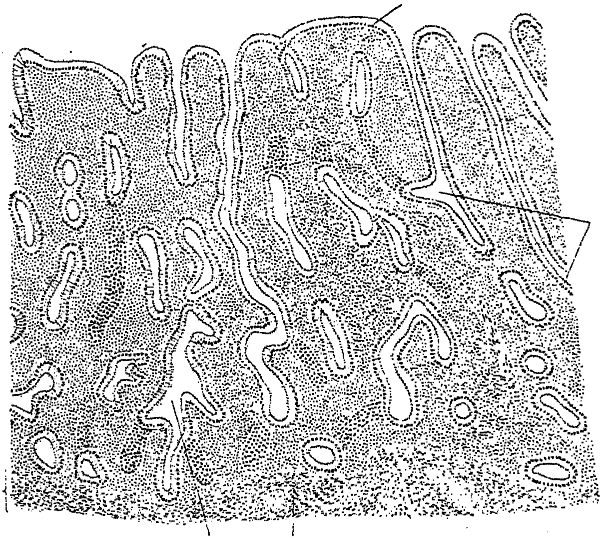
The position of the uterus *in the adult* is liable to considerable variation, depending chiefly on the condition of the bladder and rectum. When the bladder is empty the entire uterus is directed forwards, and is at the same time bent on itself at the junction of the body and cervix, so that the body lies upon the bladder. As the latter fills, the uterus gradually becomes more and more erect, until with a fully distended bladder the fundus may be directed towards the sacrum.

During menstruation the organ is enlarged, and more vascular, and its surfaces are rounder; the external orifice is rounded, its labia swollen, and the lining membrane of the body is thicker, softer, and of a darker colour.

During pregnancy the uterus becomes enormously enlarged, and in the eighth month reaches the epigastric region. The increase in size is partly due to growth of pre-existing muscular fibres, and partly to development of new fibres.

After parturition the uterus nearly regains its usual size, weighing about 42 gm.; but its cavity is larger than in the virgin state, its vessels are tortuous, and its muscular layers are more defined; the external orifice is more marked, and its edges present one or more fissures.

FIG. 1192.—A vertical section through the mucous membrane of a human uterus. (Sobotta.)



In old age the uterus becomes atrophied, and paler, and denser in texture; a more distinct constriction separates the body and cervix. The internal orifice is frequently, and the external orifice occasionally, obliterated, while the lips almost entirely disappear.

Structure.—The uterus is composed of three coats: an external or serous, a middle or muscular, and an internal or mucous.

The *serous coat* is derived from the peritoneum; it invests the fundus and the whole of the posterior or intestinal surface of the uterus; but covers the anterior or vesical surface only as far as the junction of the body and cervix. In the lower one-fourth of the intestinal surface the peritoneum is not closely connected with the uterus, being separated from it by a layer of loose cellular tissue and some large veins.

The *muscular coat* forms the chief bulk of the substance of the uterus. In the virgin it is dense, firm, of a greyish colour, and cuts almost like cartilage. It is thick opposite the middle of the body and fundus, and thin at the orifices of the uterine tubes. It consists of bundles of unstriped muscular fibres, intermixed with areolar tissue, blood-vessels, lymphatic vessels, and nerves. During pregnancy the muscular tissue becomes more prominently developed, the fibres being greatly enlarged. Although the unstriped muscular fibres interlace in all directions, they are arranged in three more or less distinct layers: external, middle and internal; the last is sometimes looked upon as a greatly hypertrophied muscularis mucosæ.

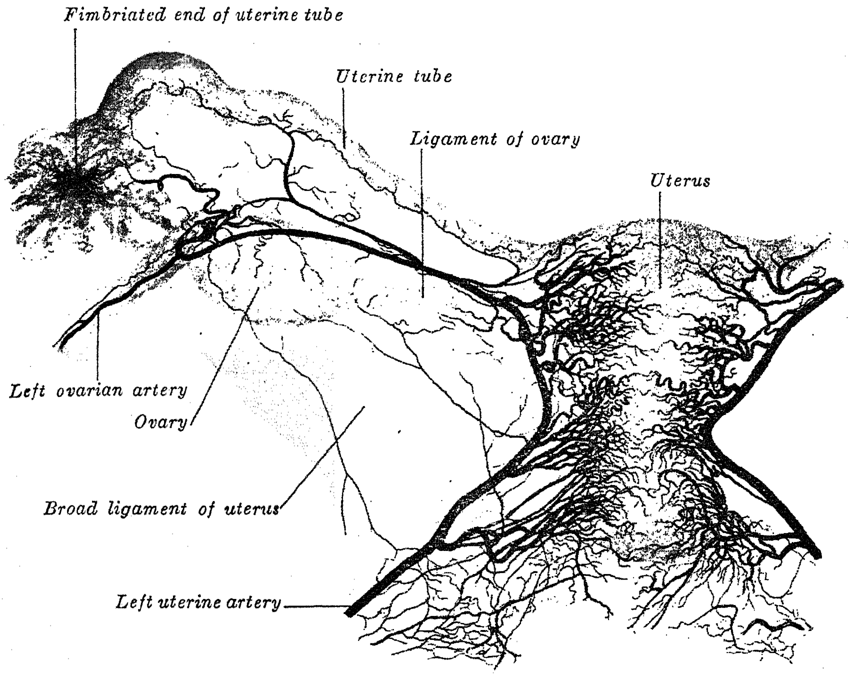
The external layer consists chiefly of longitudinal fibres which pass over the fundus, and, converging at either lateral angle of the uterus, are continued on the uterine tube, the round ligament, and the ligament of the ovary: some passing at either side into the broad ligament, and others running backwards from the cervix into the sacro-uterine ligaments. The middle layer of fibres is the thickest, but presents no regularity in its

arrangement, being disposed longitudinally, obliquely, and transversely; it contains the larger blood-vessels. The internal layer consists of longitudinal and circular fibres; at the internal orifice the circular fibres form a sphincter. The deep ends of the uterine glands come into close relation with the fibres of the internal layer.

The *mucous membrane*, sometimes named the *endometrium* (fig. 1192), is continuous, through the fimbriated extremities of the uterine tubes, with the peritoneum; and, through the external uterine orifice, with the lining of the vagina.

In the body of the uterus the mucous membrane is smooth, soft, of a pale red colour, and lined by columnar ciliated epithelium. The structure of the corium differs from that of ordinary mucous membranes, and consists of an embryonic nucleated and highly cellular form of connective tissue in which run numerous large lymphatics. In it are many tube-like *uterine glands*, which are lined with ciliated columnar epithelium and open into the cavity of the uterus. They are of small size in the unimpregnated uterus, but shortly after impregnation become enlarged and elongated, presenting a contorted or waved appearance.*

FIG. 1193.—The left uterine and ovarian arteries of an unmarried girl of 17½ years. Posterior aspect. (From a preparation by Hamilton Drummond.)



In the cervix uteri the mucous membrane is raised into two median elevations, one on the anterior, the other on the posterior, wall of the canal; from these median elevations numerous ridges (palmate folds) run upwards and lateralwards. In the upper two-thirds of the cervix, the mucous membrane is provided with numerous deep glandular follicles which secrete a clear viscid alkaline mucus; and, in addition, extending through the whole length of the canal is a variable number of little cysts, presumably follicles which have become occluded and distended with retained secretion. They are called the *ovula Nabothi.* The mucous membrane covering the lower one-half of the cervical canal presents numerous papillæ. The epithelium of the upper two-thirds is cylindrical and ciliated, but below this it loses its cilia, and, close to the external orifice, changes to stratified squamous. On the vaginal surface of the cervix the epithelium is similar to that lining the vagina, viz. stratified squamous.

Vessels and Nerves.—The *arteries* of the uterus are the uterine branch of the hypogastric artery, and the ovarian branch of the abdominal aorta (fig. 1193). They are remarkable for their tortuous course in the substance of the organ. The termination of the ovarian artery meets that of the uterine artery, and forms an anastomotic trunk from which branches are given off to supply the uterus. The *veins* are of large size, and correspond with the arteries. They end in the uterine venous plexuses. In the impregnated uterus the arteries

* Arthur Thomson (*British Medical Journal*, January 7th, 1922) discusses whether the uterine glands possess a secretory or an absorbent function.

carry the blood to, and the veins convey it away from, the intervillous space of the placenta (p. 66). The *lymphatics* are described on p. 774. The *nerves* are derived from the hypogastric and ovarian plexuses, and from the second, third and fourth sacral nerves.

Applied Anatomy.—A certain amount of anteversion or retroversion of the uterus can take place without the conditions being regarded as pathological, but when the degree of flexion at the junction of the body with the cervix becomes considerable it must be regarded as a morbid condition. This is especially true of retroversion combined with retroflexion. Retroversion alone is a falling back of the whole uterus, so that the cervix points forwards towards the os pubis; retroflexion is a bending backwards of the body, the cervix remaining in its normal position. The two conditions are usually combined. Prolapse of the uterus is another common infirmity. The organ sinks to an abnormally low level in the pelvis, and sometimes protrudes beyond the vulva. This is due to the supporting mechanism of the uterus being insufficient to sustain the strain thrown upon it.

In the treatment of uterine fibroids which require operative interference, removal of the whole body of the uterus, together with the tumours, with or without the cervix, through an abdominal incision, gives the most satisfactory results. After the abdomen has been opened the ovarian vessels are secured (one ovary at least being left, provided it be healthy) and the broad ligaments are divided. It will now be found that the uterus can be raised out of the pelvis, and a transverse incision is made through the peritoneum, where it is reflected from the front of the uterus on to the back of the bladder, and this viscus is separated from the surface of the uterus. The uterus is now turned forwards and the peritoneum of the recto-uterine excavation incised transversely. The uterus is now almost free, and is held only by the lower part of the broad ligament on either side, containing the uterine artery. A ligature is made to encircle this as close to the uterus as possible, the position of the ureter being always kept in mind, and, after having been tied, the structures are divided between the ligature and the uterus. The body of the uterus can now be removed by cutting it across at its junction with the cervix, or if desired the vaginal wall can be incised both front and back and the cervix removed together with the body. The peritoneum is finally sewn up carefully across the floor of the pelvis, with a transverse line of suture from one uterine tube to the other, so as to leave no raw surface to which small intestine can adhere.

Inflammation of the cellular tissue surrounding the cervix occasionally takes place. Laceration of the cervix by instruments or by the fœtal head frequently occurs, opening up the cellular planes and so exposing them to any infection that may be present. An inflammatory mass forms in the cellular tissue between the layers of the broad ligament or of the uterosacral ligaments, and the condition is termed *pelvic cellulitis*, or *parametritis*. This condition is usually confined to one side of the pelvis, forming a large inflammatory mass which pushes the uterus over to the opposite side. It does not always remain localised, however, but may spread widely, surrounding the rectum or the neck of the bladder, or mounting into the iliac fossa, or even to the perinephric cellular tissue. The condition may resolve or an abscess may form. In the former condition the cicatrisation of the inflammatory products produces displacements of the uterus towards the affected side of the pelvis, or may result in stricture of the rectum when that viscus has been surrounded by the process. When suppuration ensues, the pus may burst into the bladder, vagina, or rectum, or it may present above the inguinal ligament, or it may mount to the anterior abdominal wall in front of the bladder or to the posterior abdominal wall between the iliac crest and last rib. The abscess may, moreover, make its way into the buttock by passing out of the pelvis through the greater sciatic foramen, or it may pass down between the fibres of the Levator ani and appear as a secondary ischiorectal abscess.

The Vagina (fig. 1189)

The **vagina** is a canal which extends from the vestibule or cleft between the labia minora to the uterus, and is situated behind the bladder and in front of the rectum; it is directed upwards and backwards, its axis forming with that of the uterus an angle of over ninety degrees, opening forwards, but the angle varies with the conditions of the bladder and rectum. Its walls are ordinarily in contact, and the usual shape of its lower part on transverse section is that of an H, the transverse limb being slightly curved forwards or backwards, while the lateral limbs are somewhat convex towards the median line; its middle part has the appearance of a transverse slit. Its length is 7·5 cm. along its anterior wall, and 9 cm. along its posterior wall; its width gradually increases from below upwards. Its upper end surrounds the vaginal portion of the cervix uteri, a short distance from the external orifice of the uterus, its attachment extending higher on the posterior than on the anterior wall of the uterus. To the recess behind the cervix uteri the term *posterior fornix* is applied, while the smaller recesses at the sides and in front are called the *lateral* and *anterior fornices*.

The *anterior wall* of the vagina is in relation with the fundus of the bladder, and with the urethra. Its *posterior wall* is separated from the rectum by the recto-uterine excavation in its upper one-fourth, and by some connective tissue in its middle two-fourths; the lower one-fourth is separated from the anal canal by a mass of muscular and fibrous tissue, named the *perinæal body*. Its sides are enclosed between the Levatores ani muscles. As the terminal portions of the ureters pass forwards and medialwards to reach the fundus of the bladder, they run close to the lateral fornices of the vagina, and as they enter the bladder are usually placed in front of the vagina (p. 1201*).

Structure.—The vagina consists of an internal mucous lining and a muscular coat, separated by a layer of erectile tissue.

The *mucous membrane* is firmly fixed to the muscular coat; on its free surface there are two longitudinal ridges, one on the anterior and the other on the posterior wall of the vagina. These ridges are called the *columns of the vagina*, and from them numerous transverse ridges or rugæ extend lateralwards on either side. These rugæ are divided by furrows of variable depth, giving to the mucous membrane the appearance of being studded over with conical projections or papillæ; they are most numerous near the orifice of the vagina, especially before parturition. The epithelium of the mucous membrane is of the stratified squamous variety. The mucous coat contains a number of mucous crypts, but no true glands.

The *muscular coat* consists of two layers: an external longitudinal, which is by far the stronger, and an internal circular layer. The longitudinal fibres are continuous with the superficial muscular fibres of the uterus. The strongest fasciculi are those attached to the rectovesical fascia on either side. The two layers are not distinctly separable from each other, but are connected by oblique decussating fasciculi, which pass from the one layer to the other. In addition to this, the lower end of the vagina is surrounded by a band of striped muscular fibres, the *Bulbocavernosus* (Sphincter vaginæ) (p. 491).

External to the muscular coat is a layer of connective tissue, containing a large plexus of blood-vessels.

The *erectile tissue* is situated between the mucous membrane and the muscular coat; it consists of a layer of loose connective tissue, imbedded in which is a plexus of large veins, and numerous bundles of unstriped muscular fibres, derived from the circular muscular layer. The arrangement of the veins is similar to that found in other erectile tissues.

Vessels and Nerves.—The *arteries* of the vagina are derived from the vaginal, uterine, internal pudendal, and middle hæmorrhoidal branches of the hypogastric arteries. The *veins* form plexuses at the sides of the vagina, and these plexuses are drained through the vaginal veins into the hypogastric veins. The *lymphatics* are described on p. 774. The *nerves* are derived from the vaginal plexuses, and from the second, third and fourth sacral spinal nerves.

The External Genital Organs of the Female (fig. 1194)

The **external genital organs of the female** are: the mons pubis, the labia majora et minora pudendi, the clitoris, the vestibule of the vagina, the bulb of the vestibule, and the greater vestibular glands. The term *pudendum* or *vulva*, as generally applied, includes all these parts.

The **mons pubis** (mons Veneris), the rounded eminence in front of the pubic symphysis, is formed by a collection of fatty tissue beneath the skin. It becomes covered with hair at the time of puberty.

The **labia majora** are two prominent longitudinal cutaneous folds which extend downwards and backwards from the mons pubis, and form the lateral boundaries of a fissure or cleft, the *pudendal cleft or rima*, into which the vagina and urethra open. Each labium has two surfaces, an outer, pigmented and covered with crisp hairs; and an inner, smooth and beset with large sebaceous follicles. Between the two surfaces there is a considerable quantity of areolar tissue, fat, and a tissue resembling the dartos tunic of the scrotum, besides vessels, nerves, and glands. The labia are thicker in front, where they form by their meeting the *anterior labial commissure*. Posteriorly they are not really joined, but appear to become lost in the neighbouring integument, ending close to, and nearly parallel with, each other; together with the connecting skin between them, they form the *posterior labial commissure*, or posterior boundary of the pudendum. The interval between the posterior commissure and the anus, from 2·5 cm. to 3 cm. in length, constitutes the gynæcological perinæum.

The **labia minora** are two small cutaneous folds, situated between the labia

right extremity of the transverse colon are in close relationship with the liver, and abscess of this viscus sometimes bursts into the gut in this situation. The gall-bladder may become adherent to the duodenum or colon, and gall-stones may find their way into either, and may become impacted or may be discharged per anum. The mobility of the sigmoid colon renders it more liable to become the seat of a volvulus or twist than any other part of the intestine. This generally occurs in patients who have been the subjects of habitual constipation, and in whom, therefore, the mesocolon is elongated. This portion of the bowel, being loaded with fæces, falls over the part below, and so gives rise to the twist.

Hernia.—The two chief sites at which external hernia may take place are the inguinal region and the femoral canal. The description of the inguinal canal and its relations will be found on p. 481 and that of the femoral canal on p. 689. Some points in regard to the disposition of the peritoneum in these regions may, however, be recapitulated here.

Between the upper margin of the front of the pelvis and the umbilicus, the peritoneum, when viewed from behind, will be seen to be raised into five folds, with intervening depressions, by more or less prominent bands which converge to the umbilicus (fig. 1090). The middle umbilical ligament, situated in the middle line, is covered by a fold of peritoneum known as the *middle umbilical fold.* On either side of this a fold of peritoneum round the obliterated umbilical artery forms the *lateral umbilical fold.* To either side of these three cords is the inferior epigastric artery covered by the *epigastric fold.* Between these raised folds are depressions constituting the so-called foveæ. The most medial, between the middle and lateral umbilical folds, is known as the *supravesical fovea.* The intermediate one is on the medial side of the epigastric fold, and is termed the *medial inguinal fovea.* The third is lateral to the epigastric fold, and is known as the *lateral inguinal fovea.* Occasionally the inferior epigastric artery corresponds in position to the obliterated hypogastric artery, and then there is but one fold on either side of the middle line. In the usual position of the parts, the floor of the lateral inguinal fovea corresponds to the abdominal inguinal ring, and into this fovea an oblique inguinal hernia descends. On the medial side of the epigastric fold are the medial inguinal and the supravesical foveæ, and through either of these a direct hernia may descend. The whole of the space between the inferior epigastric artery, the margin of the Rectus abdominis, and the inguinal ligament, is known as Hesselbach's triangle. Below the level of the inguinal ligament is a small depression corresponding to the position of the femoral ring. It is known as the *femoral fovea*, and into it a femoral hernia descends.

Inguinal hernia.—Inguinal hernia is that form of protrusion which makes its way through the abdominal wall in the inguinal region. There are two principal varieties: lateral or oblique, and medial or direct.

In *oblique inguinal hernia* the intestine escapes from the abdominal cavity at the abdominal inguinal ring, pushing before it a pouch of peritoneum which forms the hernial sac. As it enters the inguinal canal it receives an investment from the extraperitoneal tissue and is enclosed in the infundibuliform fascia. In passing along the inguinal canal it displaces upwards the arched fibres of the Transversus and Obliquus internus, and receives a covering of Cremaster muscle and cremasteric fascia. It then passes along the front of the spermatic cord and escapes from the inguinal canal at the subcutaneous inguinal ring, becoming invested by intercrural fascia. Lastly it descends into the scrotum, receiving coverings from the superficial fascia and the skin.

The seat of stricture in oblique inguinal hernia is either the abdominal or the subcutaneous inguinal ring; most frequently at the former situation. If it is situated at the subcutaneous ring, the division of a few fibres at one point of the circumference is all that is necessary for the replacement of the hernia. If at the abdominal ring, it is necessary to divide the aponeurosis of the Obliquus externus so as to lay open the inguinal canal; in dividing the aponeurosis the incision should be directed parallel to the inguinal ligament, and the constriction at the abdominal ring should then be divided directly upwards.

When the intestine passes along the inguinal canal and escapes from the subcutaneous ring into the scrotum, it is called a *scrotal* hernia. If the intestine does not pass into the scrotum, but merely bulges through the subcutaneous ring, it is called a *bubonocele.*

The great majority of varieties of oblique inguinal hernia depend upon congenital defects in the saccus vaginalis, the pouch of peritoneum which precedes the descent of the testis. Normally this pouch is closed before birth, closure commencing at two points, viz. at the abdominal inguinal ring and at the top of the epididymis, and gradually extending until the whole of the intervening portion is converted into a fibrous cord. From failure in the completion of this process, variations in the relation of the hernial protrusion to the testis and tunica vaginalis are produced; these constitute distinct varieties of inguinal hernia, viz. the hernia of the funicular process and the complete congenital variety.

Where the saccus vaginalis remains patent throughout, the cavity of the tunica vaginalis communicates directly with that of the peritoneum. The intestine descends along this pouch into the cavity of the tunica vaginalis, which constitutes the sac of the hernia, and the gut lies in contact with the testis. Though this form of hernia is termed *complete congenital* (fig. 113), the term does not imply that the hernia existed at birth,

The **external urethral orifice** is placed about 2·5 cm. behind the glans clitoridis and immediately in front of the orifice of the vagina: it usually assumes the form of a short, sagittal cleft with slightly raised margins.

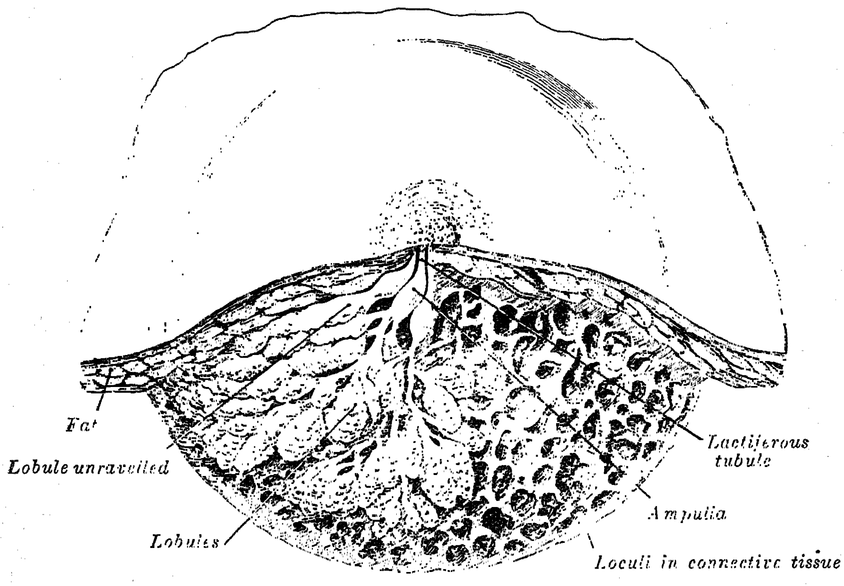
The **bulb of the vestibule** is the homologue of the urethral bulb and adjoining part of the corpus cavernosum urethræ of the male, and consists of two elongated masses of erectile tissue, placed one on either side of the vaginal orifice and united to each other in front by a narrow median band termed the *pars intermedia*. Each lateral mass measures about 3 cm. in length. Their posterior ends are expanded and are in contact with the greater vestibular glands; their anterior ends are tapered and joined to one another by the pars intermedia; their deep surfaces are in contact with the inferior fascia of the urogenital diaphragm; superficially they are covered by the Bulbocavernosus.

The **greater vestibular glands** (glands of Bartholin) are the homologues of the bulbo-urethral glands in the male. They consist of two small, round or oval bodies of a reddish-yellow colour, situated one on either side of the vaginal orifice, in contact with the posterior end of each lateral mass of the bulb of the vestibule. Each gland opens by means of a duct, about 2 cm. long, immediately lateral to the hymen, in the groove between its attached border and the labium minus.

The Mammæ

The **mammæ** or **breasts** secrete the milk, and are accessory glands of the generative system. They exist in the male as well as in the female, but in the former only in the rudimentary state. In the female they are two large hemispherical eminences lying within the superficial fascia on the front and

Fig. 1195.—A dissection of the lower half of the mamma during the period of lactation. (Luschka.)

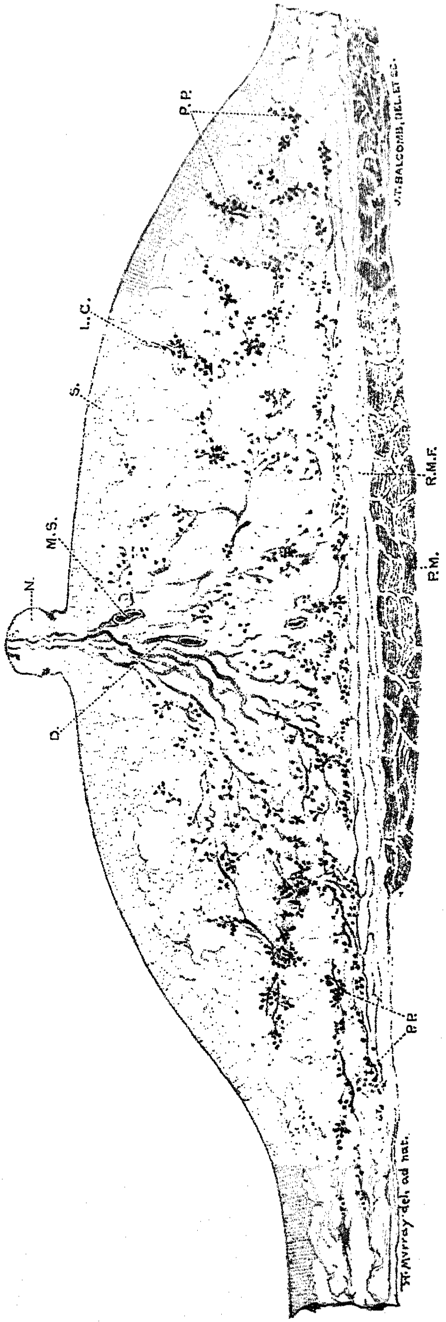


sides of the chest; each extends from the second rib above to the sixth rib below, and from the side of the sternum to near the mid-axillary line. In weight and size they differ at different periods of life, and in different individuals. Before puberty they are small, but they enlarge as the generative organs become more completely developed. They increase during pregnancy, and especially after delivery, and become atrophied in old age. The deep surface of each is nearly circular, flattened, or slightly concave, and has its long diameter directed upwards and lateralwards towards the axilla; it is separated from the fascia covering the Pectoralis major, Serratus anterior, and Obliquus externus

abdominis by loose connective tissue. The subcutaneous surface of the mamma is convex, and presents, just below the centre, a small conical prominence, the papilla.

The **mammary papilla or nipple** is a cylindrical or conical eminence situated about the level of the fourth intercostal space. It is capable of undergoing a sort of erection from mechanical excitement, a change mainly due to the contraction of its muscular fibres. It is of a pink or brownish hue, its surface wrinkled and provided with secondary papillæ; and it is perforated by from fifteen to twenty orifices, the apertures of the lactiferous ducts. The base of the mammary papilla is encircled by a coloured area of skin called the *areola*. In the virgin the areola is of a delicate rosy hue; about the second month after impregnation it enlarges and acquires a darker tinge, and as pregnancy advances it may assume a dark brown, or even black colour. This colour diminishes as soon as lactation is over, but is never entirely lost. These changes in the colour of the areola are of importance in forming a conclusion in a case of suspected first pregnancy. Near the base of the papilla, and upon the surface of the areola, are numerous sebaceous glands, the *areolar glands*, which become much enlarged during lactation and present the appearance of small tubercles beneath the skin; they secrete a peculiar fatty substance, which serves as a protection to the skin of the papilla. The mammary papilla consists of numerous vessels, intermixed with plain muscular fibres, which are principally arranged in a circular manner around the base, but a few fibres radiate from base to apex.

Fig. 1196.—Horizontal section of the mammary gland at the level of the nipple in a multiparous female, aged forty years. (Stiles.) (From Quain's Anatomy, vol. iii. part iv.)

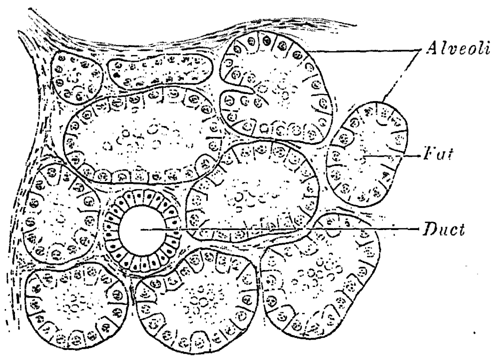


D. lactiferous tubule; L.C. ligament of Cooper; M.S. Ampulla of lactiferous tubule; N. mammary papillæ or nipple; P.M. Pectoralis major; P.P. peripheral processes; R.M.F. retromammary fat; S. skin.

Structure (figs. 1195 to 1197).—The mamma consists (*a*) of gland-tussue; (*b*) of fibrous tissue, connecting its lobes; and (*c*) of fatty tissue in the intervals between the lobes. The subcutaneous tissue encloses the mamma and sends numerous septa into it to support its various lobules. From that part of the fascia which covers the mamma fibrous processes pass forwards to the skin and the mammary papilla; these are named by Sir A. Cooper the *ligamenta suspensoria*. The gland-tissue is of a pale reddish colour, firm in texture, and forms a lobulated mass which is flattened from before backwards and thicker in the centre than at the circumference. It consists of numerous lobes, and these are composed of lobules, connected together by areolar tissue, blood-vessels, and ducts. The smallest lobules

consist of a cluster of rounded alveoli which open into the smallest branches of the lactiferous ducts; these branches unite to form larger ducts which end in the excretory ducts or *tubuli lactiferi.* The tubuli lactiferi vary from fifteen to twenty in number; they converge towards the areola, beneath which they form dilatations, or *ampullæ,* which serve as reservoirs for the milk. At the base of the papilla they become contracted, and pursue a straight course to its summit, perforating it by separate orifices considerably narrower than the ducts themselves. The ducts are composed of areolar tissue containing longitudinal and transverse elastic fibres; they are lined by columnar epithelium resting on a basement-membrane. The epithelium of the alveoli differs according to the state of activity of the organ. In the gland of a woman who is not pregnant or suckling, the alveoli are very small and solid, being filled with a mass of granular polyhedral cells. During pregnancy the alveoli enlarge, and the cells undergo rapid multiplication. At the commencement of lactation, the cells in the centre of the alveolus undergo fatty degeneration, and are eliminated in the first milk, as *colostrum corpuscles.* The peripheral cells of the alveolus remain, and form a single layer of granular, short columnar cells, with spherical nuclei, lining the basement-membrane. When the gland is active, oil globules are found in the alveolar cells and are discharged into the lumen, constituting the milk-globules. When the acini are distended by the accumulation of the secretion the lining epithelium becomes flattened.

FIG. 1197.—A section through a portion of the mamma.



The *fibrous tissue* invests the entire surface of the mamma, and sends down septa between its lobes, connecting them together.

The *fatty tissue* covers the surface of the gland, and occupies the interval between its lobes. It usually exists in considerable abundance, and determines the form and size of the gland. There is no fat immediately beneath the areola and papilla.

Vessels and Nerves.—The *arteries* supplying the mamma are derived from the thoracic branches of the axillary artery, and from the internal mammary and intercostal arteries. The *veins* describe an anastomotic circle round the base of the papilla, called by Haller the *circulus venosus.* From this circle, branches transmit the blood to the circumference of the gland, and end in the axillary and internal mammary veins. The *lymphatics* are described on p. 777. The *nerves* are derived from the anterior and lateral cutaneous branches of the fourth, fifth, and sixth thoracic nerves.

Applied Anatomy.—The ducts descending from the mammary papilla radiate through the gland, and when an incision is made into the breast the scalpel should be directed radially, from the centre to the periphery, so that it may not pass across the ducts. A milk duct may become obstructed and distended, forming a tumour known as a *galactocele.* Abscess frequently occurs about the mamma, more often in women who are lactating, especially in those who have cracks or fissures about the papilla. The abscess may be between the septa, in the gland-tissue itself, or it may lie beneath the skin by the side of the papilla and superficial to the mamma, or it may form beneath the mamma, between it and the deep fascia. Free incision, radiating from the papilla, is required in such cases.

Cystic formation of many different kinds is commonly seen in the mamma; in some cases it is due to dilatation of the larger ducts or of the lymph-spaces throughout the gland; in others the cysts occur in new growths of the mamma, or as the result of obstruction of the smaller ducts by chronic inflammatory processes.

Malignant growths are seen more often in the mamma than in any other organ; they are of great variety, but the commonest is the spheroidal-celled cancer, the cells of which are intermingled with a varying amount of fibrous tissue. A hard contracting tumour-mass results, which drags on the fibrous septa between the lobes so that fixation or retraction of the papilla ensues, and sooner or later the malignant infiltration invades the surrounding gland-tissues, the skin, the deep fascia and Pectorales, and even the chest-wall and pleura. The lymph-glands beneath the Pectorales and those situated towards the apex of the axilla become early involved with secondary malignant deposit, and later the supraclavicular glands enlarge. In other cases the mediastinal glands may be involved, when the disease is situated on the medial side of the papilla.

The operation for removal of a mamma affected with malignant disease should be an extensive procedure, with the object of extirpating all fascial planes and lymphatic structures that may become infected. The incision commences below, over the upper part of the sheath of the Rectus, encloses the mamma by an ellipse, and is then continued on towards the apex of the axilla. The loss of blood can be diminished by planning the

operation so as to ligature the branches of the axillary artery near their origins, and the perforating branches of the internal mammary as they come through the intercostal muscles. This is done by first clearing the axillary vein and ligaturing the subscapular, the lateral thoracic, and the thoraco-acromial arteries as they appear. The pectoralis major and minor are divided close to their insertions, and turned medialwards so as to expose the perforating arteries as they come through the intercostal muscles before entering the pectoral muscle. The reflection of the skin, which has not yet been completed, and the removal of the pectoralis major now give rise to very little bleeding. The wound is then closed, drainage is provided, and firm pressure is applied with the dressings. It will be noted that the clavicular portion of the Pectoralis major is left intact, as it is of considerable service for the subsequent movements of the arm, the utility of which is but slightly impaired.

THE DUCTLESS GLANDS*

The **ductless glands** are distinguished from other glands by the fact that they have no ducts, the products of their activity being discharged into the blood either directly, or indirectly through the lymphatic vessels. Each of these glands produces an *internal secretion* which contains one or more active substances or *hormones*,† and is distributed to other organs and tissues by the blood-stream. In some of the other glands of the body, groups of cells are present which exhibit all the characteristics of the ductless glands, i.e. their secretions are not discharged through the gland-ducts but are carried off in the blood-vessels or lymphatics; important examples of these are the cell-islets of the pancreas (p. 1180), the interstitial cells of the testes (p. 1212) and ovaries (p. 1226), and the glands of the stomach (p. 1151) and duodenum (p. 1160).

The products of the ductless glands differ so greatly from one another that, with the exception of the chromaffin group, it is impossible to classify them physiologically. For descriptive purposes, however, they may be grouped according to the systems from which they mainly originate, thus:

1. Developed chiefly from the digestive tube.
    - Thyreoid gland.
    - Parathyreoid glands.
    - Thymus.
2. Developed chiefly from the neural tube.
    - (*a*) From the brain.
        - Pineal body (p 836).
        - Hypophysis (p. 838).
            - Posterior lobe from neural tube.
            - Anterior lobe from buccal ectoderm.
    - (*b*) From the sympathetic system.
        - Paraganglia.
        - Suprarenal glands.
            - Medulla from sympathetic system.
            - Cortex from cœlomic epithelium.
3. Developed chiefly from the vascular system.
    - Lymph and hæmolymph glands.
    - Glomus coccygeum.
    - Spleen (partly from cœlomic epithelium).

The Thyreoid Gland (fig. 1198)

The **thyreoid gland** is a highly vascular organ, situated at the front and sides of the lower part of the neck, opposite the fifth, sixth and seventh cervical vertebræ. It is ensheathed by the pretracheal layer of the fascia colli, and

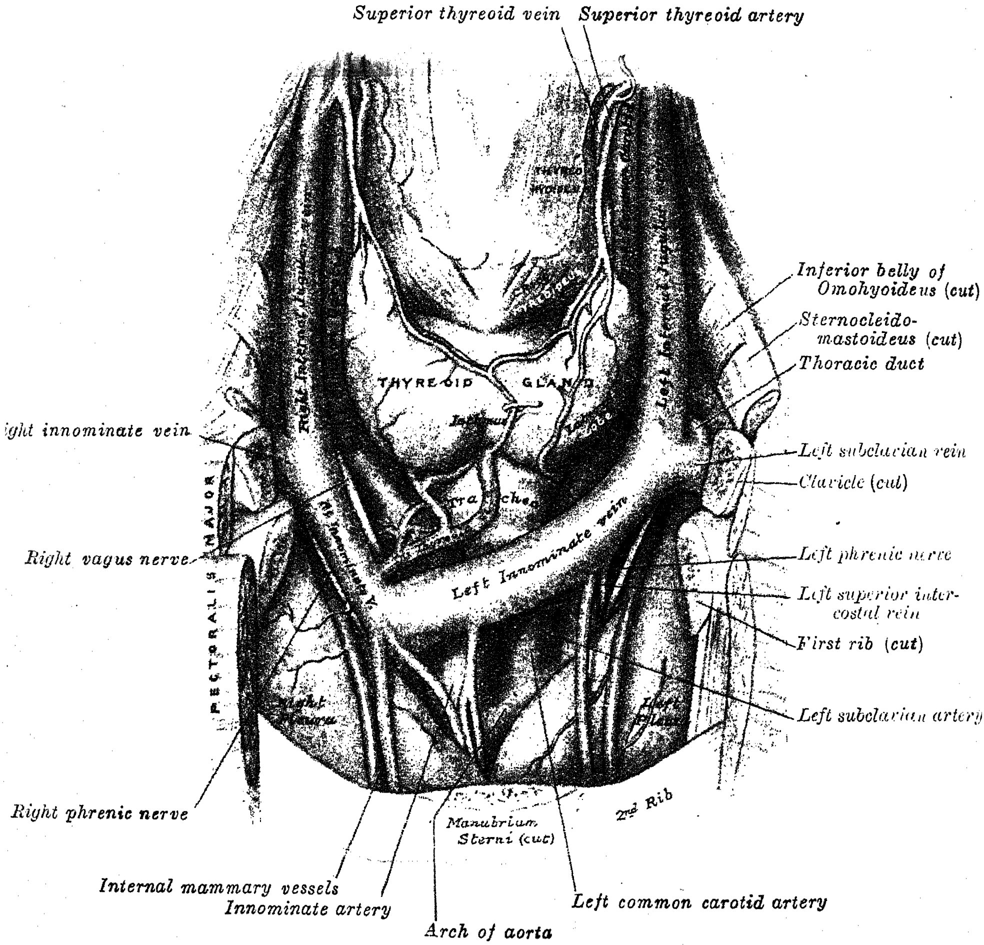
* The term "endocrine organs" is commonly used to designate glands and tissues which produce internal secretions.

† Sharpey Schafer proposes the term "autacoid substances," and divides them into *hormones* or excitatory secretions and *chalones* or inhibitory secretions.

consists of right and left lobes connected across the middle line by a narrow portion, the *isthmus*. Its weight is somewhat variable, but is usually about 30 gm. It is slightly heavier in the female, in whom it becomes enlarged during menstruation and pregnancy.

The *lobes* are conical in shape, the apex of each being directed upwards and lateralwards as far as the junction of the middle with the lower one-third of the thyreoid cartilage; the base is on a level with the fifth or

FIG. 1198.—Dissection of the lower part of the neck, and the upper part of the thorax. Anterior aspect.



sixth tracheal ring. Each lobe is about 5 cm. long; its greatest width is about 3 cm., and its thickness about 2 cm. The *lateral or superficial surface* is convex, and covered by the skin, the superficial and deep fasciæ, the Sternocleidomastoideus, the superior belly of the Omohyoideus, the Sternohyoideus and Sternothyreoideus, and beneath the last muscle by the pretracheal layer of the deep fascia, which forms a capsule for the gland. The *medial surface* is moulded over the thyreoid and cricoid cartilages, the trachea, the Constrictor pharyngis inferior and posterior part of the Cricothyreoideus, the œsophagus (particularly on the left side of the neck), the superior and inferior thyreoid arteries, and the recurrent nerve. The *posterior surface* overlaps the common carotid artery, and, as a rule, the parathyreoid glands. The *anterior border* is thin, and inclines obliquely from above downwards towards the middle line of the neck.

The *isthmus* connects together the lower parts of the two lobes; it measures about 1·25 cm. transversely, and the same vertically, and usually covers the second, third and fourth rings of the trachea. Its situation and size present, however, many variations. It is covered by the skin and fascia, and close to the middle line, on either side, by the Sternothyreoideus. Across its upper border runs an anastomotic branch uniting the two superior thyreoid arteries; at its lower border are the inferior thyreoid veins. Sometimes the isthmus is altogether wanting.

A third lobe, of conical shape, called the *pyramidal lobe*, frequently extends from the upper part of the isthmus, or from the adjacent portion of either lobe, but most commonly the left, to the hyoid bone. It is occasionally quite detached, or may be divided into two or more parts.

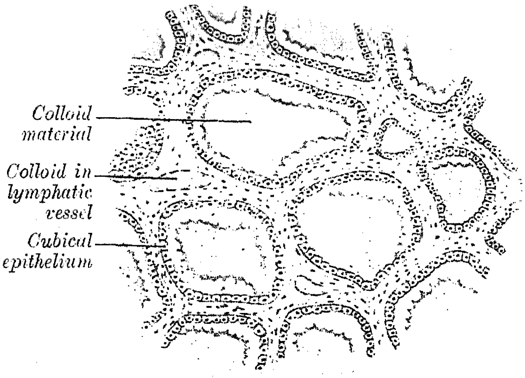
A fibrous or muscular band is sometimes found attached, above, to the body of the hyoid bone, and below, to the isthmus of the gland, or its pyramidal lobe; when muscular, it is termed the *Levator glandulæ thyreoideæ*.

Small detached portions of thyreoid tissue are sometimes found in the vicinity of the lateral lobes or above the isthmus; they are called *accessory thyreoid glands*.

Structure.—The thyreoid gland is closely invested by a thin capsule of connective tissue, which sends incomplete septa into its substance, dividing it into masses of irregular form and size. The gland is of a brownish-red colour, and is made up of a number of closed vesicles, just visible to the naked eye, containing a yellow glairy fluid, and separated from each other by intermediate connective tissue (fig. 1198).

The vesicles of the thyreoid of the adult are generally closed spherical sacs; but in some young animals (e.g. dogs) they are more or less tubular and branched. Each is lined by a single layer of cubical epithelium. There does not appear to be a basement-membrane, so that the epithelial cells are in direct contact with the connective tissue reticulum. The vesicles are of various sizes, and contain a viscid, homogeneous, semi-fluid, slightly yellowish, colloid material; red blood-corpuscles are found in various stages of disintegration and decolorisation, the yellow tinge being probably due to hæmoglobin, which is set free from the corpuscles. The colloid material contains an iodine compound, *iodothyrin*, and, when coagulated by hardening reagents, is readily stained by eosin and other dyes. It passes out between the cubical cells and is absorbed into the blood or lymph.

Fig. 1199.—A section through the thyreoid gland of a sheep. × 160.



Vessels and Nerves.—The *arteries* supplying the thyreoid gland are the superior and inferior thyreoid arteries; sometimes there is an additional branch (a. thyreoidea ima) from the innominate artery or the arch of the aorta, which ascends upon the front of the trachea. The arteries are remarkable for their large size and frequent anastomoses. The *veins* form a plexus on the surface of the gland and on the front of the trachea; from this plexus the superior, middle, and inferior thyreoid veins arise; the superior and middle end in the internal jugular vein, the inferior in the innominate vein. The capillary blood-vessels form a dense plexus in the connective tissue around the vesicles, between the epithelium of the vesicles and the endothelium of the lymphatics which surround a greater or smaller part of the circumference of the vesicle. The *lymphatic vessels* run in the interlobular connective tissue, not uncommonly surrounding the arteries which they accompany and communicate with a network in the capsule of the gland; they may contain colloid material. They end in the thoracic duct and the right lymphatic trunk. The *nerves* are derived from the middle and inferior cervical ganglia of the sympathetic.

Applied Anatomy.—The secretion of the thyreoid gland has a profound influence over metabolic processes generally, and exercises its effects on the whole autonomic nervous system.

When the gland is congenitally absent, or has undergone atrophy in early life, the physical and mental development of the body is greatly interfered with, and a form of dwarfism with mental deficiency, named cretinism, results. If, during adult life, atrophy

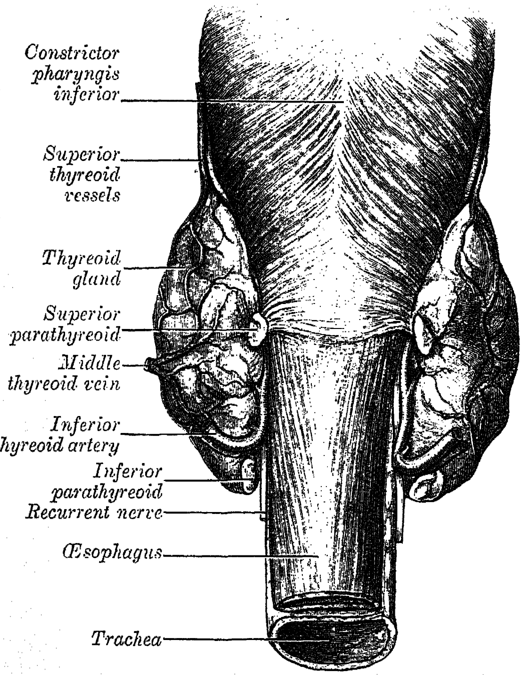
of the gland occurs, or the whole gland be removed by operation the condition known as myxœdema is brought about; this is characterised by marked apathy, dulling of all the bodily and mental functions, and the deposit of mucoid material in the subcutaneous tissues.

The effects of hyperactivity of the gland are well seen in exophthalmic goitre, a condition in which the outstanding symptoms are enlargement of the thyreoid gland, persistent tachycardia, tremor, and exophthalmos (protrusion of the eyeballs). Any enlargement of the thyreoid gland is called a goitre. The swelling may take the form of a diffuse hypertrophy of the whole gland, giving rise to the *parenchymatous goitre,* this being mainly due to the hypertrophy of the thyreoid follicles themselves; in other cases a *fibroid* form of goitre is produced owing to the increase in the interstitial connective tissue; in others, again, the vascular changes may preponderate, and many large pulsating vessels may be present. Much more commonly, however, the enlargement is due to adenomatous new growth in the substance of the thyreoid; these tumours are usually innocent, and tend to destroy life only by pressure on the air-passages. A single tumour is the rule, but in some instances a very large number may be present. They tend to show marked mucoid degeneration, and so become converted into cystadenomata, and finally into what appear to be simple cysts. These tumours may attain an enormous size and may involve practically the whole gland. Malignant tumour-growth more rarely attacks the organ.

When a goitre continues to grow, and especially when there are commencing symptoms of tracheal pressure, operative interference becomes necessary. This is not difficult, if an encapsuled tumour is to be dealt with, provided the anatomical layers covering it are remembered. In such a case it is necessary to make an incision suited to the size and situation of the tumour, and having divided the deep cervical fascia, to retract the Sternocleidomastoideus or divide it if necessary. The Sternohyoideus and Sternothyreoideus next require division, or in some cases their fibres may be separated and drawn asunder, and beneath is found the ensheathing capsule derived from the pretracheal fascia; this requires division, and exposes the true capsule of the thyreoid gland. In the case of an adenoma or cyst, this true capsule then needs incision before the tumour can be effectually shelled out, and this is usually accomplished with very little hæmorrhage, and without any of the main vessels of the gland requiring ligature.

Partial extirpation of the thyreoid, viz. the removal of one lateral lobe with division of the isthmus, may be required in cases of parenchymatous goitre, and in the diffuse form of adenomatous disease. It is a more radical proceeding, and carries with it a much greater risk from hæmorrhage; there is also a danger of wounding the recurrent nerve. The whole gland must never be removed, as such a procedure is followed by the development of myxœdema. In hemithyreoidectomy a free incision is indicated—dividing muscles, if necessary—to expose the true gland capsule, but at the same time avoiding injury to the large vessels which lie beneath it. The superior and inferior pedicles containing the respective thyreoid arteries are then isolated and clamped on either side and divided between the clamps. The half gland is then turned over towards the middle line, and the isthmus ligatured and divided. Some venous bleeding is apt to occur from connexions with the tracheal veins, and must be stopped. The pedicles are then securely ligatured and the wound closed. In dealing with the inferior thyreoid artery, the position of the recurrent nerve must be borne in mind, so as not to ligature or divide it. Temporary aphonia not uncommonly follows from bruising of the nerve, and if nothing more serious has occurred soon passes off.

FIG. 1200.—The parathyreoid glands. Posterior aspect.



THE PARATHYREOID GLANDS

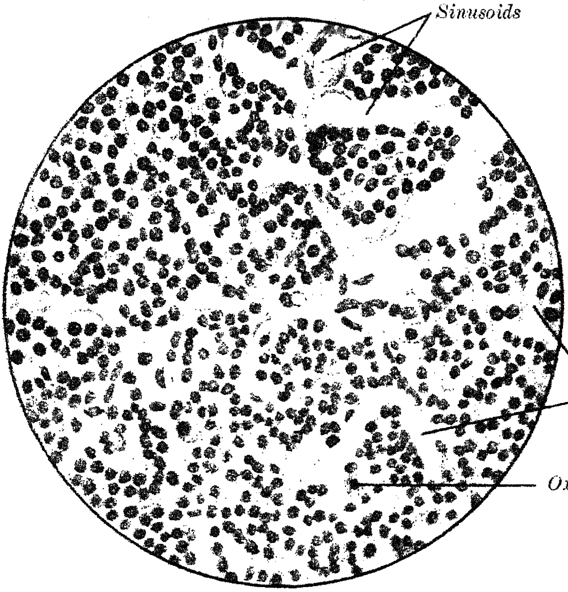
The parathyreoid glands (fig. 1200) are small brownish-red bodies, situated as a rule between the posterior borders of the lateral lobes of the thyreoid gland and its capsule. They measure on an average about 6 mm.

in length, and from 3 mm. to 4 mm. in breadth, and usually present the appearance of flattened oval discs. They are divided, according to their situation, into *superior* and *inferior*. The superior, usually two in number, are the more constant in position, and are situated one on either side, at the level of the lower border of the cricoid cartilage, behind the junction of the pharynx and œsophagus. The inferior, also usually two in number, may be applied to the lower edge of the lateral lobes of the thyreoid gland, or placed at some little distance below the thyreoid gland, or found in relation to one of the inferior thyreoid veins.*

In man, they number four as a rule; fewer than four were found in less than 1 per cent. of over a thousand persons (Pepere †), but more than four in over 33 per cent. of 122 bodies examined by Civalleri. In addition, numerous minute islands of parathyreoid tissue may be found scattered in the connective tissue and fat of the neck round the parathyreoid glands proper, and quite distinct from them.

Structure.—Microscopically the parathyreoid glands consist of intercommunicating columns of cells supported by connective tissue containing a rich supply of blood-capillaries (sinusoids). Most of the cells are clear, but some, larger in size, contain oxyphil granules (fig. 1201). Vesicles containing colloid are sometimes found.

FIG. 1201.—A section of a human parathyreoid gland. Stained with hæmotoxylin and eosin. ×400.



Applied Anatomy.—No doubt the parathyreoid glands produce an internal secretion essential to the well-being of the human economy; but it is still a matter of dispute what symptoms of disease are produced by their removal and suppression of their secretion. Pepere believes that they show signs of exceptional activity during pregnancy, and that parathyreoid insufficiency is a main factor in the production of tetany in infants and adults, of eclampsia, and of certain sorts of fits.

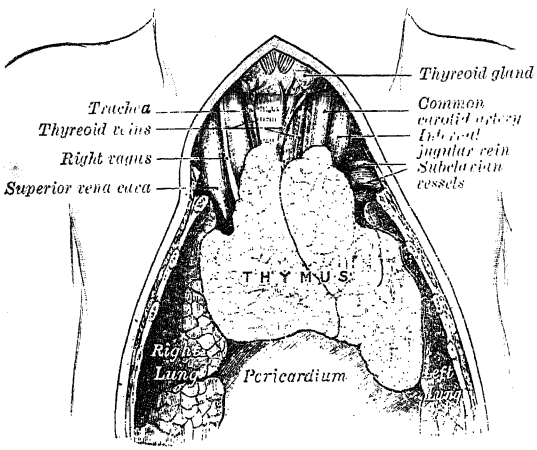
THE THYMUS (fig. 1202)

The **thymus** increases in size until the age of puberty, after which it dwindles and undergoes a gradual involution. Hammar maintains that it may persist and function even in advanced life. If examined when its growth is most active,

* Consult an article by D. A. Welsh, *Journal of Anatomy and Physiology*, vol. xxxii.
† Consult *Le Ghiandole paratiroidee*, by A. Pepere, Turin, 1906.

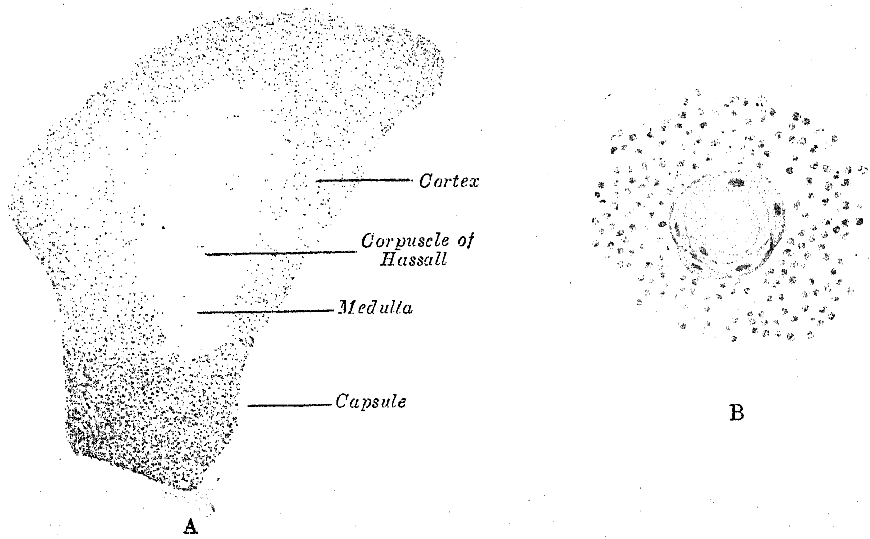
it will be found to consist of two lateral lobes placed in close contact along the middle line, situated partly in the thorax, partly in the neck, and extending from the fourth costal cartilage upwards, as high as the lower border of the thyreoid gland. It is covered by the sternum, and by the origins of the Sternohyoidei and Sternothyreoidei. Below, it rests upon the pericardium, being separated from the aortic arch and great vessels by a layer of fascia. In the neck it lies on the front and sides of the trachea, behind the Sternohyoidei and Sternothyreoidei. The two lobes generally differ in size; they are occasionally united by connective tissue, so as to form a single mass; sometimes they are separated by an intermediate lobe. The thymus is of a pinkish-grey colour, soft, and lobulated on its surfaces. At birth it weighs about 13 gm., and at puberty between 35 and 40 gm.; it is heavier in the male than in the female.

FIG. 1202.—The thymus of a full-time fœtus. Exposed *in situ*.



Structure.—Each lateral lobe is composed of numerous lobules held together by delicate areolar tissue; the entire gland being enclosed in an investing capsule of a similar but denser structure. The primary lobules vary in size and are made up of a number of small nodules or follicles, which are irregular in shape and are more or less fused together,

FIG. 1203.—A, A section through a follicle of the thymus of a kitten. ×60; B, a corpuscle of Hassall. ×350. Stained with picrocarmine.



especially towards the interior of the gland. Each follicle (fig. 1203 A) is from 1 mm. to 2 mm. in diameter and consists of a cortical and a medullary portion; it is enclosed in a connective tissue capsule, from which septa pass into its substance, but do not extend as far as the medullary portion of the follicle. The *cortical portion* is mainly composed of lymphocytes, supported by a network of finely branched cells, which is continuous with a similar network in the medullary portion. This network forms an adventitia to the blood-

vessels. In the *medullary portion* the lymphoid cells are fewer, and the reticulum is coarser than in the cortex; it contains nest-like bodies, the *concentric corpuscles* of Hassall. These corpuscles are composed of a central mass, consisting of one or more granular cells, and of a capsule which is formed of concentrically arranged epithelioid cells (fig. 1203 B). Eosinophil and polymorphonuclear leucocytes are also found in the gland.

Each follicle is surrounded by a vascular plexus, from which vessels pass into the interior, and radiate from the periphery towards the centre, forming a second zone just within the margin of the medullary portion. In the centre of the medullary portion there are very few vessels, and they are of minute size.

The cortical part begins to atrophy before the medullary part, and its decrease in size is mainly owing to a diminution in the number of lymphocytes.

Vessels and Nerves.—The *arteries* supplying the thymus are derived from the internal mammary, and from the superior and inferior thyreoids. The *veins* end in the left innominate vein, and in the thyreoid veins. The *lymphatics* are described on p. 778. The *nerves* are exceedingly minute; they are derived from the vagi and sympathetic. Branches from the descendens hypoglossi and phrenic reach the investing capsule, but do not penetrate the substance of the gland.

Applied Anatomy.—Sudden death—'thymus death'—with heart-failure, and with or without acute respiratory embarrassment, has been recorded in a number of infants and children in whom the thymus was considerably enlarged, and the lymphatic tissues throughout the body showed general hypertrophy, but who showed no other evidence of disease. Such deaths have often occurred during the administration of anæsthetics, particularly chloroform. How far the enlarged thymus was responsible for the death of these patients, and, if it was responsible, how far its action was mechanical, are points that have been much disputed. Short of producing this sudden death, it appears that thymic enlargement may cause attacks of respiratory stridor, or noisy and difficult breathing, and spasmodic attacks of asthma—'thymic asthma'—which may be frequently repeated and may even result in death.

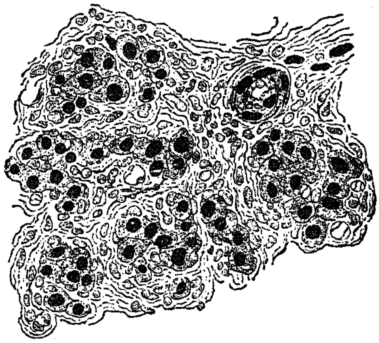
Primary tumours of the thymus are rare forms of mediastinal new growth, and are usually sarcomas.

The Chromaffin Organs

It was pointed out on p. 100 that the tissue from which the sympathetic ganglia are formed consists of a syncytium of sympathochromaffin cells which are soon differentiated into (*a*) small sympathetic nerve-cells, and (*b*) large *chromaffin cells*, so named because of their affinity for chromic salts, which stain them a brown colour. These chromaffin cells are subsequently grouped to form the chromaffin organs, the chief of which are the paraganglia, and the medullary portions of the suprarenal glands.

The **paraganglia** are found in two chief groupings: (1) as small masses of chromaffin cells, placed either within the capsules of the sympathetic ganglia or in close contact with them; (2) as small groups of chromaffin cells scattered throughout the sympathetic plexuses. The two largest masses in this latter group are the aortic bodies of Zuckerkandl and the glomera carotica.

Fig. 1204.—A section through a part of a human glomus caroticum. (Schaper.) Highly magnified. (From Quain's Elements of Anatomy.)



Numerous blood-vessels are seen in section among the gland-cells.

The *aortic bodies of Zuckerkandl* are two small brownish-coloured bodies which lie one on either side of the abdominal aorta at the level of the origin of the inferior mesenteric artery, in intimate relationship with the abdominal aortic plexus of the sympathetic. They are of considerable size (8-10 mm. long) in the new-born child, and may be united to one another across the front of the abdominal aorta. After birth they gradually atrophy, and become invisible to the naked eye shortly after puberty.

Structure.—The aortic bodies consist of masses of polygonal or cubical epithelium, imbedded in a wide-meshed capillary plexus.

The *glomera carotica* (carotid bodies), two in number, are situated one on either side of the neck, behind the common carotid artery at its point of

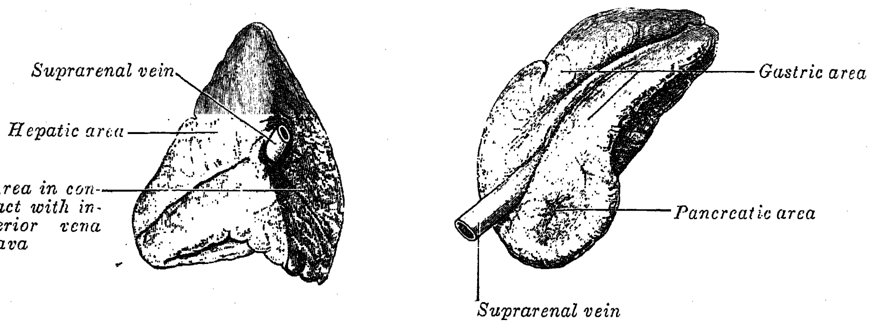
bifurcation into the external and internal carotid trunks. They are reddish-brown in colour and oval in shape, the long diameter measuring about 5 mm.

Structure.—Each glomus is invested by a fibrous capsule and consists largely of spherical or irregular masses of chromaffin cells (fig. 1204)—the masses being more or less isolated from one another by septa which extend inwards from the deep surface of the capsule. The cells are polyhedral in shape, and each contains a large nucleus imbedded in finely granular protoplasm. Numerous nerve-fibres, derived from the sympathetic plexus on the carotid artery, are distributed throughout the organ, and a network of large sinusoidal capillaries ramifies amongst the cells.

The Suprarenal Glands (figs. 1205, 1206)

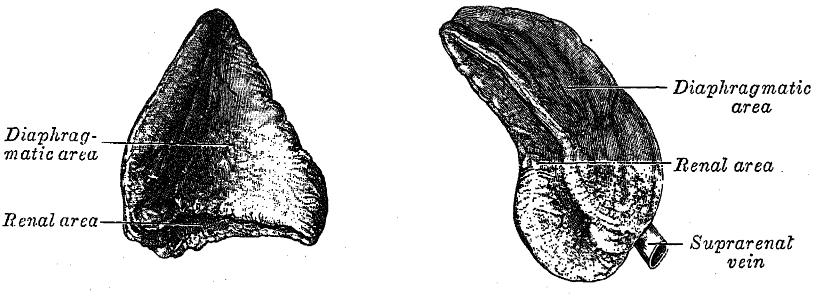
The **suprarenal glands** are two small flattened bodies of a yellowish colour, situated, one on either side of the middle line, at the posterior part of the abdomen, behind the peritoneum, and immediately above and in front of the

Fig. 1205.—The suprarenal glands. Anterior aspect.



upper end of the kidney. They are surrounded by areolar tissue containing a considerable amount of fat. The right gland is somewhat pyramidal in shape, bearing a resemblance to a cocked hat; the left is semilunar, and is usually larger and placed at a higher level than the right. They measure from 30 mm. to 50 mm. in height; about 30 mm. in breadth, and from 4 mm. to 6 mm. in thickness. The average weight of each is from 3 gm. to 4 gm.

Fig. 1206.—The suprarenal glands. Posterior aspect.



Relations.—The *right suprarenal gland* is situated behind the inferior vena cava and the right lobe of the liver, and in front of the Diaphragm and upper end of the right kidney. It is roughly triangular in shape; its base, directed downwards, is in contact with the medial and anterior surfaces of the upper end of the right kidney. Its *anterior surface* looks forwards and lateralwards, and has two areas: a medial, narrow and non-peritoneal, which lies behind the inferior vena cava; and a lateral, somewhat triangular, in contact with the

liver. The upper part of the latter surface is devoid of peritoneum, and is in relation with the lower and medial angle of the bare area of the liver, while its inferior portion may be covered by peritoneum, reflected on to it from the inferior layer of the coronary ligament; occasionally the duodenum overlaps the inferior portion. A little below the apex, and near the anterior border of the gland, is a short furrow termed the hilum, from which the right suprarenal vein emerges to join the inferior vena cava. Its *posterior surface* is divided into upper and lower parts by a curved ridge; the upper, slightly convex, rests upon the Diaphragm; the lower, concave, is in contact with the upper end and the adjacent part of the anterior surface of the right kidney.

The *left suprarenal gland* is crescentic in shape, its concavity being adapted to the medial border of the upper part of the left kidney. Its medial border is convex, its lateral concave; its upper end is narrow, its lower rounded. Its *anterior surface* has two areas: an upper, covered by the peritoneum of the omental bursa which separates it from the cardiac end of the stomach and sometimes from the superior extremity of the spleen; and a lower which is not covered by peritoneum, but is in contact with the pancreas and lienal artery. Near the lower part of the anterior surface is the hilum, which is directed downwards and forwards. From it the left suprarenal vein emerges to join the left renal vein. Its *posterior surface* is divided into two areas by a ridge; the lateral area rests on the kidney, the medial and smaller, on the left crus of the Diaphragm.

FIG. 1207.—A section through a part of a suprarenal gland. (Magnified.)

Small *accessory suprarenal* glands are often found in the connective tissue round the suprarenal glands; they are sometimes present in the spermatic cord and epididymis, and in the broad ligament of the uterus.

Structure.—The suprarenal gland is closely invested by a capsule of connective tissue from which trabeculæ pass into the substance of the gland; the capsule may contain smooth muscular fibres. On section, the gland is seen to consist of two portions (fig. 1207): an external, the cortex, and an internal, the medulla. The cortex constitutes the larger part of the organ, and is of a deep yellow colour; the medulla is soft, pulpy, and of a dark red or brown colour.

The *cortex* consists of a fine connective tissue network, in which is imbedded the glandular epithelium. The epithelial cells are polyhedral in shape and possess rounded nuclei; many of the cells contain coarse granules, others lipoid globules. Owing to the differences in the arrangement of the cells three distinct zones can be made out: (1) The *zona glomerulosa*, situated beneath the capsule, consists of cells arranged in rounded groups, with here and there indications of an alveolar structure. (2) The *zona fasciculata*, continuous with the zona glomerulosa, is composed of columns of cells arranged in a radial manner; these cells contain fine granules and in many instances globules of lipoid material. (3) The *zona reticularis*, in contact with the medulla, consists of cylindrical columns of cells irregularly arranged; these cells often contain pigment-granules which give this zone a darker appearance than the rest of the cortex.

The *medulla* is extremely vascular, and is composed of a mass of large finely granular, chromaffin cells, permeated by venous sinusoids. This portion of the gland is richly supplied with non-medullated nerve-fibres, and here and there sympathetic ganglion cells are found.

The suprarenal gland is large in the fœtus, owing to the great development of the inner layer of the cortex. This layer has been named the *boundary zone* by Elliott and Armour. Its cells contain no lipoid granules. This zone disappears soon after birth and is absent in anencephalic fœtuses.

In connexion with the development of the medulla from the sympathochromaffin tissue, it is to be noted that this portion of the gland secretes a substance, *adrenalin*, which has the property of stimulating all sympathetic nerve-endings.

Vessels and Nerves.—The *arteries* supplying the suprarenal glands are numerous and of comparatively large size; they are derived from the aorta, and the inferior phrenic and renal arteries. In the cortical part of the gland they break up into capillaries which end in the sinusoids of the medullary portion; the latter open into the veins near the centre of the medulla.

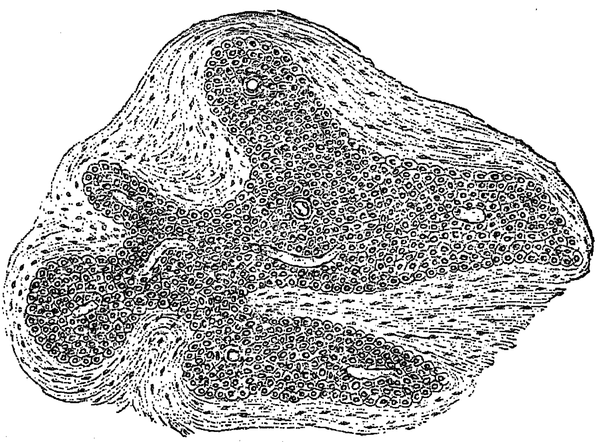
The *suprarenal vein* emerges from the hilum of the gland; that of the right gland opens into the inferior vena cava, that of the left into the renal vein.

The *lymphatics* end in the lumbar glands.

The *nerves* are exceedingly numerous, and are derived from the splanchnic nerves through the cœliac and renal plexuses, and, according to Bergmann, from the phrenic and vagus nerves. They enter the lower and medial part of the capsule, traverse the cortex, and end around the cells of the medulla. They have numerous small ganglia developed upon them in the medullary portion of the gland.

Applied Anatomy.—The suprarenal *cortex* is derived from the cœlomic epithelium of the Wolffian ridge, and is connected with the sexual glands; it is related to growth and development in some way, and is often found to be hypertrophied in patients with chronic kidney disease and high blood-pressure. The *medulla*, on the other hand, is neuro-ectodermal in origin, and closely connected with the sympathetic nervous system. When the suprarenal medulla is destroyed by tuberculosis, to which the glands are prone, or by the pressure of a new growth, the secretion of adrenalin becomes inadequate, and Addison's disease develops. Patients with Addison's disease become pigmented in various parts of the body, possibly from irritation of the sympathetic, and complain of great weakness, lack of energy, nausea, and severe attacks of vomiting. Their blood-pressure is low, the whole nervous system is depressed, and death follows after a period of months or years, usually from asthenia. Tumours derived from the suprarenal itself, or from misplaced suprarenal 'rests' occurring in such organs as the kidney or liver, may be either benign or malignant, and are classed together under the name 'hypernephroma.' In children the malignant hypernephroma is often associated with obesity and precocity. The benign hypernephroma, or suprarenal adenoma, appears to produce no symptoms except those due to its slow enlargement.

FIG. 1208.—A section through an irregular nodule of the glomus coccygeum. × 85. (Sertoli.) (From Quain's Elements of Anatomy.)



The section shows the fibrous covering of the nodule, the blood-vessels within it, and the epithelial cells of which it is constituted.

THE GLOMUS COCCYGEUM

The **glomus coccygeum** (coccygeal body) is placed in front of, or immediately below, the tip of the coccyx. It is about 2·5 mm. in diameter and is irregularly oval in shape; several smaller nodules are found around or near the main mass.

Structure.—The glomus coccygeum consists of irregular masses of round or polyhedral cells (fig. 1208), the cells of each mass being grouped around a dilated sinusoidal capillary vessel. Each cell contains a large round or oval nucleus, the protoplasm surrounding which is clear and is not stained by chromic salts.*

THE SPLEEN (LIEN)

The **spleen** is situated principally in the left hypochondriac region of the abdomen, but its upper end extends into the epigastric region; it lies between the fundus of the stomach and the Diaphragm. It is the largest of the

* Consult the following article: 'Über die menschliche Steissdrüse,' von J. W. Thomson Walker, *Archiv für mikroskopische Anatomie und Entwickelungsgeschichte*, Band 64, 1904.

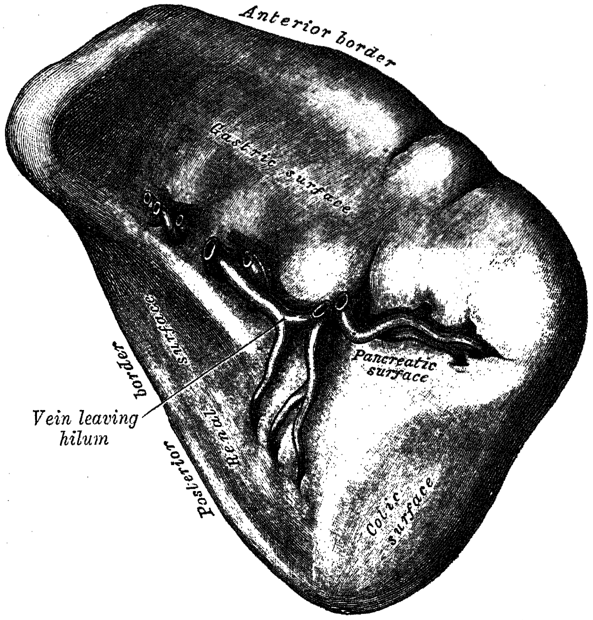
ductless glands, and is of an oblong, flattened form, soft, of very friable consistence, highly vascular, and of a dark purplish colour.

Relations.—The *diaphragmatic surface* is convex, smooth and is directed upwards, backwards, and to the left, except at its upper end, where it is directed slightly medialwards. It is in relation with the under surface of the Diaphragm, which separates it from the ninth, tenth, and eleventh ribs of the left side, and the intervening lower border of the left lung and pleura.

The *visceral surface* (fig. 1209) is divided by a ridge into an anterior or gastric, and a posterior or renal portion.

The *gastric surface*, directed forwards, upwards, and medialwards, is broad and concave. It is in contact with the posterior wall of the stomach, and below the stomach with the tail of the pancreas. It presents near its medial border a long fissure, termed the *hilum*. This is pierced by several irregular apertures for the entrance and exit of vessels and nerves.

FIG. 1209.—The visceral surface of the spleen.



The *renal surface*, directed medialwards and downwards, is somewhat flattened. It is considerably narrower than the gastric surface, and is in relation with the upper part of the anterior surface of the left kidney and occasionally with the left suprarenal gland.

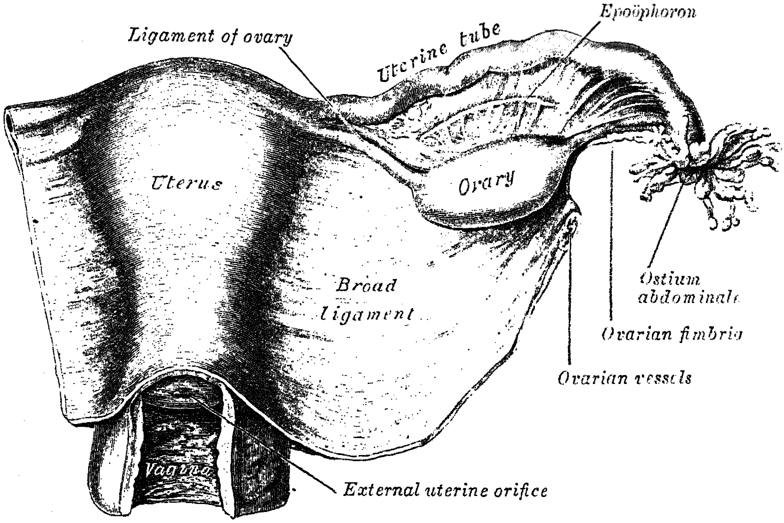
The *upper end* is directed towards the vertebral column, where it lies on a level with the eleventh thoracic vertebra. The *lower end* or *colic surface* is flat, triangular in shape, and rests upon the left flexure of the colon and the phrenicocolic ligament, and is generally in contact with the tail of the pancreas. The *anterior border*, free and thin, is often notched near its lower end; it separates the diaphragmatic from the gastric surface. The *posterior border*, blunter and more rounded than the anterior, separates the renal from the diaphragmatic surface; it corresponds to the lower border of the eleventh rib and lies between the Diaphragm and left kidney. The *inferior border* separates the diaphragmatic from the colic surface, and the *intermediate margin* intervenes between the renal and gastric surfaces.

The spleen is almost entirely surrounded by peritoneum, which is firmly adherent to its capsule. It is held in position by two folds of this membrane. One, the *lienorenal ligament*, is derived from the peritoneum where the wall of the general peritoneal cavity comes into contact with the omental bursa between the left kidney and the spleen; the lienal vessels pass between its two layers (fig. 1093). The other fold, the *gastrolienal ligament* (gastrosplenic omentum), also consists of two layers, and is formed by the meeting of the walls of the general peritoneal cavity and of the omental bursa between the spleen and stomach (fig. 1093); the short gastric and left gastro-epiploic branches of the lienal artery run between its two layers. The lower end of the spleen is supported by the phrenicocolic ligament (p. 1144).

The size and weight of the spleen vary at different periods of life, in different individuals, and in the same individual under different conditions. *In the adult*, it is usually about 12 cm. in length, 7 cm. in breadth, and 3 or 4 cm. in thickness, and weighs about 200 gm.

blood-vessels and nerves pass to the hilum of the ovary. The *free border* is convex, and is directed towards the ureter. The uterine tube arches over the ovary,

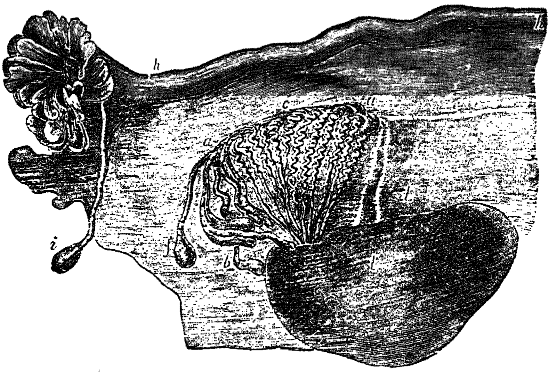
FIG. 1183.—The uterus and the right broad ligament. Posterior aspect. The broad ligament has been spread out and the ovary drawn downwards.



running upwards in relation to its mesovarian border, curving over its tubal extremity, and then passing downwards on its free border and medial surface.

In the fœtus, the ovaries are situated, like the testes, in the lumbar region near the kidneys, but they gradually descend into the pelvis (p. 156).

FIG. 1184.—The adult left ovary, epoöphoron, and uterine tube. Posterior aspect. (From Farre, after Kobelt.)



a, a. Epoöphoron formed from the upper part of the Wolffian body. *b.* Remains of the uppermost tubes sometimes forming hydatids. *c.* Middle set of tubes. *d.* Some lower atrophied tubes. *e.* Atrophied remains of the Wolffian duct. *f.* The terminal bulb or hydatid. *h.* The uterine tube. *i.* Hydatid attached to the extremity. *l.* The ovary.

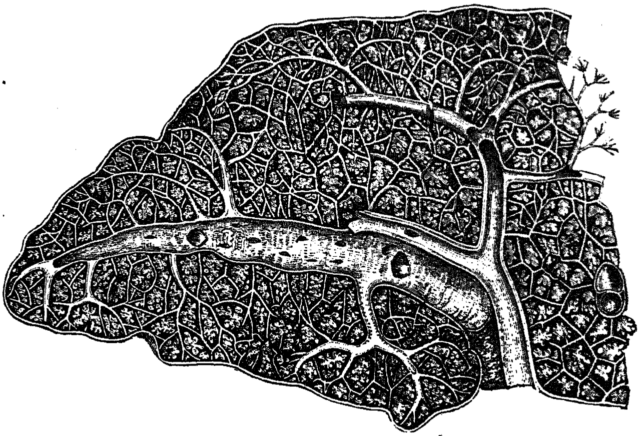
Structure (fig. 1185).—The surface of the ovary is covered by a layer of cubical cells. This epithelium gives to the ovary a dull grey colour as compared with the shining smoothness of the peritoneum; the transition between the squamous epithelium of the peritoneum and the cubical cells covering the ovary is usually marked by a line around the anterior border of the ovary.

The ovary consists of a number of vesicular ovarian follicles imbedded in the meshes of a stroma or framework.

The *stroma* is abundantly supplied with blood-vessels, and consists for the most part of spindle-shaped cells with a small amount of ordinary connective tissue. Many of these cells are unstriped muscle-cells. On the surface of the organ is a condensed layer known as the *tunica albuginea.* The stroma of the ovary also contains groups of *interstitial cells* resembling those of the testis.

Each branch runs in the transverse axis of the organ, from within outwards, diminishing in size during its transit, and giving off in its passage smaller branches, some of which pass to the anterior, others to the posterior part. These ultimately leave the trabecular sheaths, and terminate in the proper substance of the spleen in small tufts or pencils of

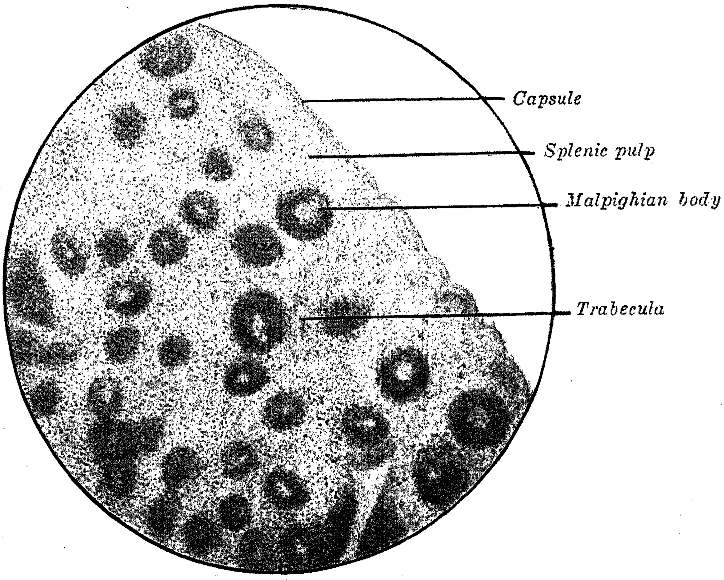
FIG. 1211.—A transverse section through the human spleen, showing the distribution of the splenic artery and its branches.



minute arterioles, which open into the interstices of the reticulum formed by the branched sustentacular cells. The branches of the splenic artery are 'end arteries' (p. 595).

The *arterioles* differ in structure from the larger arterial vessels in that their outer coat consists of lymphoid tissue. This coat exhibits localized spheroidal thickenings, termed the *Malpighian bodies* of the spleen (fig. 1212). These bodies vary in size from about 0·25 mm. to 1 mm. in diameter. In transverse sections, the artery, in the majority of cases, is found in an eccentric position. The Malpighian bodies are visible to the naked

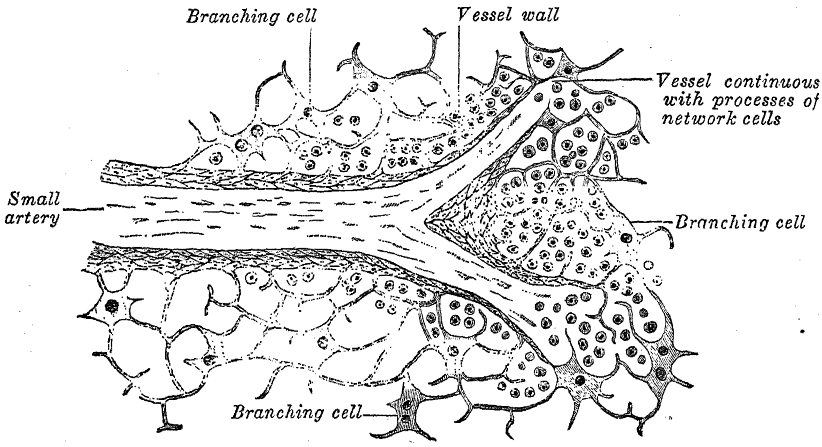
FIG. 1212.—A section through a portion of the human spleen. Stained with hæmatoxylin and eosin. × 15.



eye on the surface of a fresh section of the organ, appearing as minute semi-opaque dots of a whitish colour in the dark substance of the pulp. The reticulum of the lymphoid tissue is made up of extremely fine fibrils, and is comparatively open in the centre of the body, but closer at its periphery.

The arterioles end by opening freely into the splenic pulp; their walls become much attenuated, they lose their tubular character, and the endothelial cells ramify, their processes being directly connected with those of the reticular cells of the pulp (fig. 1213). The blood thus finds its way into the interstices of the reticulated tissue of the splenic pulp. It is then collected by the rootlets of the veins, which begin much in the same way as the arteries end. The connective tissue corpuscles of the pulp arrange themselves in rows, in such a way as to form an elongated space or sinus. They become elongated and spindle-shaped, and overlap each other at their extremities, and thus form a sort of endothelial lining of the path or sinus, which is the radicle of a vein. On the outer surface of these sinuses are seen delicate transverse lines or markings, which are due to minute elastic fibrils arranged in a circular manner. Thus the channel obtains an external investment, and gradually becomes converted into a small vein, which after a short course acquires a coat of ordinary connective tissue, lined by a layer of flattened epithelial cells continuous with the supporting cells of the pulp. The smaller veins unite to form larger ones; these do

Fig. 1213.—A section through the spleen, showing the termination of a small blood-vessel.



not accompany the arteries, but soon enter the trabecular sheaths of the capsule, and by their junction form six or more branches, which emerge from the hilum, and, uniting, constitute the lienal vein, the largest radicle of the portal vein.

The veins are remarkable for their numerous anastomoses.

The lymphatics are described on p. 771.

The *nerves* are derived from the cœliac plexus and are chiefly non-medullated. They are distributed to the blood-vessels and to the smooth muscle of the capsule and trabeculæ.

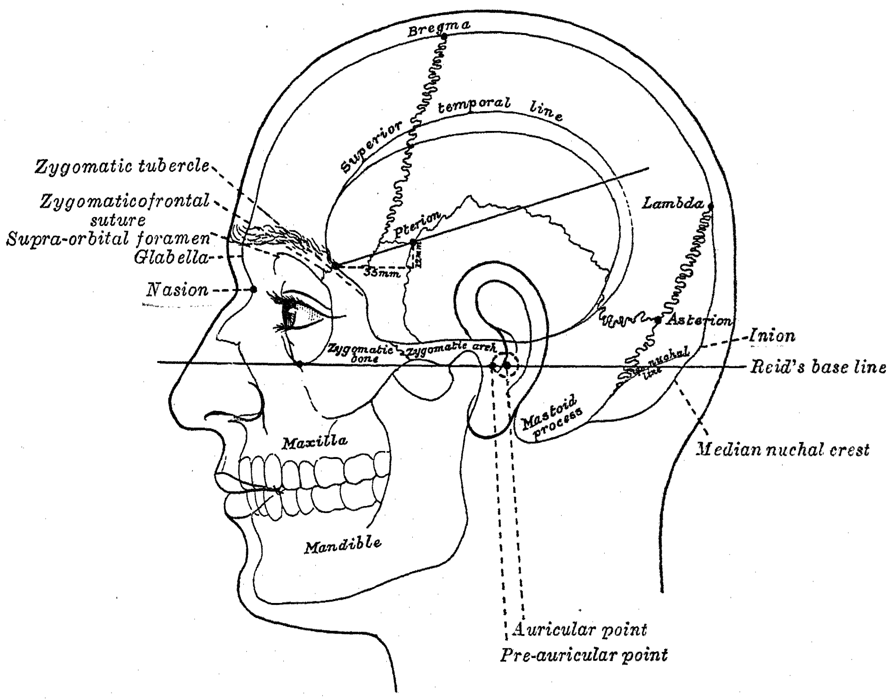
Applied Anatomy.—Injury of the spleen is less common than that of the liver, on account of its protected situation and connexions. It may be ruptured by direct or indirect violence; torn by a broken rib; or injured by a punctured or gunshot wound. When the organ is enlarged, the chance of rupture is increased. The great risk is hæmorrhage, owing to the vascularity of the organ and the absence of a proper system of capillaries. The injury is not, however, necessarily fatal, and this would appear to be due, in a great measure, to the contractile power of the capsule, which narrows the wound and prevents the escape of blood. In cases where the diagnosis is clear, and the symptoms indicate danger to life, laparotomy must be performed, and the spleen removed. When removing the spleen it must be remembered that the tail of the pancreas is in contact with it, and should be avoided in ligaturing the vessels.

SURFACE ANATOMY AND SURFACE MARKINGS

THE SURFACE ANATOMY OF THE HEAD AND THE NECK

THE **bones** (fig. 1214).—The *external occipital protuberance* (inion) is situated behind, in the middle line, at the upper end of the nuchal furrow, and the *superior nuchal lines* run lateralwards from it, one on either side. Above these lines the vault of the cranium is so thinly covered with soft structures that the form of

FIG. 1214.—A side view of the head, showing the surface relations of the bones.



this part of the head is almost that of the upper portion of the occipital, the parietal and the frontal bones. The superior nuchal lines run lateralwards to the mastoid portions of the temporal bones, from which the *mastoid processes* project downwards and forwards behind the auriculæ. The anterior and posterior borders, the apex, and the external surface of the mastoid process are available for surface examination; the anterior border lies immediately behind the concha, and the apex is nearly on a level with the lobule of the auricula. In front of the ear the *zygomatic arch* can be felt throughout its entire length; its narrow posterior end is situated

a little above the level of the tragus; its broad anterior end is continued into the zygomatic bone. The upper border of the arch is less distinct than the lower, but can be followed into the *superior temporal line.* Anteriorly, this line begins at the zygomatic process of the frontal bone as a curved ridge which runs at first forwards and upwards and then backwards on the frontal bone, separating the forehead from the temporal fossa. It then crosses the parietal bone, where, though less marked, it can generally be recognised. Finally, it curves downwards and forwards, and, passing above the opening of the external acoustic meatus, ends in the posterior root of the zygomatic arch.

Near the line of the greatest transverse diameter of the head are the *parietal tuberosities,* one on either side; further forwards, on the forehead, are the *frontal tuberosities,* which vary in prominence in different individuals. Below the frontal tuberosities are the *superciliary arches*; they are absent in infancy, and are, as a rule, small in the female. In some cases the prominence of these arches is related to the size of the frontal sinuses, but frequently there is no such relationship. Between the superciliary ridges is a smooth, somewhat triangular area, the *glabella,* and below this is the *nasion* or frontonasal suture.

Below the nasion the *nasal bones,* scantily covered by soft tissues, can be traced to their junctions with the nasal cartilages, and on either side of the nasal bones the complete outline of the *orbital margin* can be made out. At the junction of the medial with the intermediate one-third of the supra-orbital margin the *supra-orbital notch,* when present, can be felt; near the medial end of the infra-orbita margin is a little tubercle which serves as a guide to the position of the lacrimal sac. Below and lateral to the orbit, on either side, the *zygomatic bone* forms the prominence of the cheek; its posterior margin is easily felt, and on it just above the level of the lateral palpebral commissure is the *zygomatic tubercle.* A slight depression, about 1 cm. above this tubercle, indicates the position of the *zygomatico-frontal suture.* Below the orbit a considerable part of the anterior surface, and the whole of the alveolar process, of the *maxilla,* can be palpated. Almost the entire outline of the *mandible* can be recognised; the condyle lies in front of the tragus and below the zygomatic arch, and from it the posterior border of the ramus descends to the angle; from the angle to the symphysis the lower rounded border of the body of the bone is readily traced; the lower part of the anterior border of the ramus and the alveolar process can be made out without difficulty. In the receding angle below the chin is the *hyoid bone,* and the finger can be carried along the bone to the tip of its greater cornu, which is most readily appreciated by pressing on one side of the bone, and thus rendering the cornu of the opposite side prominent beneath the skin.

The transverse processes of the first, sixth, and seventh cervical vertebræ can be felt. That of the first is about 1 cm. below and in front of the mastoid process of the temporal bone and can be recognised readily by pressing upwards and inwards behind the angle of the mandible; that of the sixth is opposite to, and that of the seventh a little below, the cricoid cartilage.

The **joints and muscles.**—The *mandibular articulation* is superficial and is situated below the posterior end of the zygomatic arch, in front of the external acoustic meatus. Its position can be ascertained by defining the condyle of the mandible; when the mouth opens, the condyle advances out of the mandibular fossa on to the articular tubercle of the temporal bone, and a depression is felt in the situation of the joint.

With the exceptions of the Masseter and Temporalis the outlines of the muscles of the head and face cannot be traced on the surface. The *Masseter* imparts fulness to the hinder part of the cheek; if firmly contracted, as when the teeth are clenched, its quadrilateral outline is plainly visible; its anterior border forms a prominent vertical ridge, behind which is a considerable fulness especially marked at the lower part of the muscle. The *Temporalis,* a fan-shaped muscle, fills the temporal fossa, and stands out in strong relief when in action. The muscles of the scalp are so thin that the contour of the skull is perceptible beneath them. Those of the face are small, covered by soft skin and often by a considerable layer of fat, and their outlines are therefore concealed; they serve, however, to round off and smooth prominent borders, and to fill up what would otherwise be unsightly angular depressions. Thus the *Orbicularis oculi* rounds off the prominent margin of the orbit, and the *Procerus* fills in the sharp depression below the glabella. In like manner the *labial muscles,* converging to the lips, and assisted by the superimposed

fat, fill up the sunken hollow of the lower part of the face. When in action the facial muscles produce the various expressions, and in addition throw the skin into numerous folds and wrinkles.

By the contraction of the *Platysma* the skin of the neck is thrown into oblique ridges parallel with the fasciculi of the muscle. The *Sternocleidomastoideus* has the most important influence on the surface form of the neck (figs. 1215, 1216). When the muscle is at rest its anterior border forms an oblique rounded edge ending below in the outline of the sternal head; the posterior border is only distinct for about 2 cm. or 3 cm. above the middle of the clavicle. When the muscle is contracted, the sternal head stands out as a sharply defined ridge, while the clavicular head is flatter and less prominent; between the two heads is a slight depression.

FIG. 1215.—An anterolateral view of the head and neck.

The middle portion of the muscle appears as an oblique elevation with a thick, anterior border, best marked in its lower part. The sternal heads of the two muscles are separated by a V-shaped depression (jugular notch), the floor of which is formed by the *Sternohyoideus* and *Sternothyreoideus*. The lateral border of the *Scalenus anterior* is just under cover of and parallel with the posterior border of the Sternocleidomastoideus.

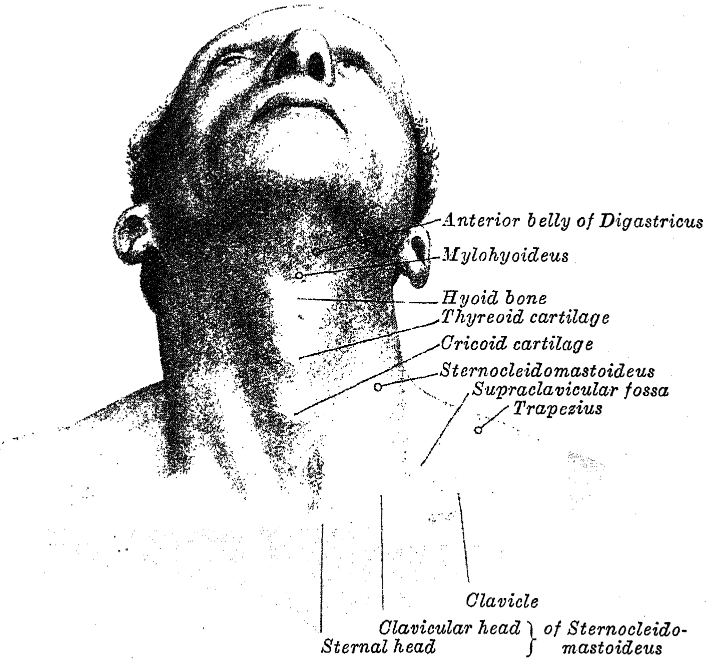
Above the hyoid bone, near the middle line, the anterior belly of the *Digastricus* gives rise to a slight convexity.

The anterior border of the *Trapezius* produces a faint ridge running downwards and forwards from the superior nuchal line to the junction of the intermediate with the lateral one-third of the clavicle. Between the Sternocleidomastoideus and the Trapezius is the posterior triangle of the neck, the lower part of which appears as a shallow concavity—the supraclavicular fossa. In this fossa, the inferior belly of the *Omohyoideus*, when in action, causes a cord-like elevation a little above and almost parallel to the clavicle.

The **arteries**.—The positions of several of the larger arteries can be ascertained from their pulsations.

The *subclavian artery* is felt on making pressure downwards, backwards, and medialwards behind the lateral margin of the clavicular head of the Sternocleidomastoideus; the *transverse cervical artery* may be detected parallel to, and about a finger's breadth above, the clavicle. The *common* and *external carotid arteries* can be recognised immediately beneath the anterior edge of the Sternocleidomastoideus, and the *external maxillary artery* can be traced over the inferior border of the mandible at the anterior edge of the Masseter, about 3 cm. in front of the angle of the mandible. The pulsation of the *occipital artery* may be felt about 3 cm. or 4 cm. lateral to the external occipital protuberance, and that of the *posterior auricular artery* in the groove between the mastoid process and the auricula. The course of the *superficial temporal artery* can be readily followed upwards across the

FIG. 1216.—A front view of the neck.



posterior end of the zygomatic arch to a point about 4 cm. above the arch, where it divides into its frontal and parietal branches; the pulsation of the frontal branch is frequently visible on the side of the forehead. The *supra-orbital artery* can usually be detected immediately above the supra-orbital notch or foramen.

The **larynx and trachea.**—In the receding angle below the chin, the hyoid bone (p. 1258), situated opposite the lower part of the third cervical vertebra, can easily be made out; when the head is erect the hyoid bone is on the same level as the lower border of the mandible. Immediately below it, is the laryngeal prominence (pomum Adami) of the thyreoid cartilage; the space between the hyoid bone and the thyreoid cartilage is occupied by the hyothyreoid membrane. The outlines of the laminæ and cornua of the thyreoid cartilage are readily palpated; below this cartilage is a depression corresponding to the middle cricothyreoid ligament. The level of the vocal folds (true vocal cords) corresponds to the middle of the anterior margin of the thyreoid cartilage. The anterior part of the cricoid cartilage forms an important landmark on the front of the neck; it lies opposite the sixth cervical vertebra, and indicates the junctions of the pharynx with the œsophagus, and of the larynx with the trachea. Below the cricoid cartilage the trachea can be felt, but only in thin subjects are its rings distinguishable; as a rule there are seven or eight rings above the jugular notch of the sternum, and of these the second, third, and fourth are covered by the isthmus of the thyreoid gland. The normal thyreoid gland cannot be felt.

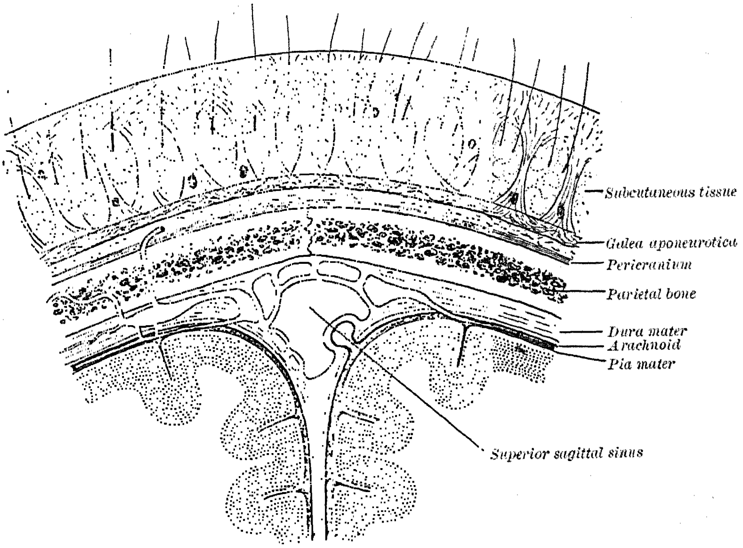
The **submaxillary gland.**—On either side of the neck the superficial portion of the submaxillary gland, as it lies partly under cover of the body of the mandible, can be felt. To palpate the entire gland the head should be thrown forwards to relax the investing layer of the fascia colli; the index finger of one hand is placed in the digastric triangle, that of the other hand is placed on the floor of the mouth, under the tongue; the gland is easily made out between the fingers.

THE SURFACE MARKINGS OF SPECIAL REGIONS OF THE HEAD AND NECK

The Cranium

The **scalp.**—The soft parts covering the upper surface of the skull form the scalp and comprise the following layers (fig. 1217): (1) skin, (2) subcutaneous tissue, (3) Occipitalis, Frontalis, and galea aponeurotica, (4) subaponeurotic tissue, (5) pericranium. The subcutaneous tissue consists of a close meshwork of fibres, the

Fig. 1217.—A coronal section through the scalp and skull. Diagrammatic.



meshes of which contain fatty tissue; the fibres bind the skin and galea aponeurotica firmly together, so that when the Occipitalis or the Frontalis is in action the skin moves with the aponeurosis. The subaponeurotic tissue is much looser in texture, and permits the movement of the galea aponeurotica over the underlying pericranium.

The **bony landmarks** (fig. 1214).—In addition to the bony points already described, which can be determined by palpation, the following are utilised for surface markings:

Asterion.—The point of meeting of the lambdoid, masto-occipital, and masto-parietal sutures; it lies 4 cm. behind and 12 mm. above the level of the auricular point.

Auricular point.—The centre of the orifice of the external acoustic meatus.

Bregma.—The meeting-point of the coronal and sagittal sutures; it lies at the point of intersection of the middle line of the scalp with a line drawn vertically upwards through the pre-auricular point.

Lambda.—The point of meeting of the lambdoid and sagittal sutures; it is in the middle line about 6·5 cm. above the inion.

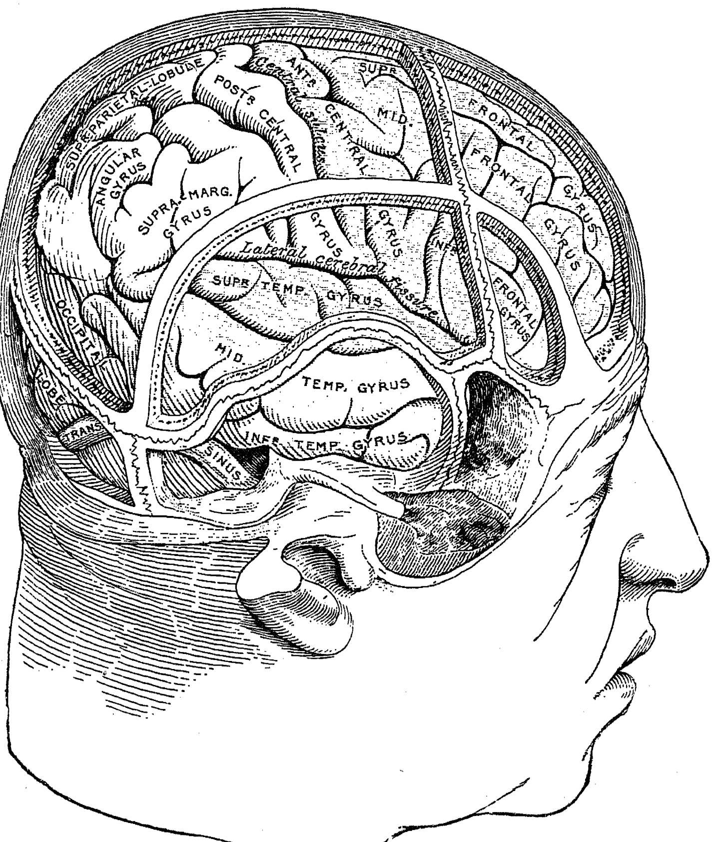
Pre-auricular point.—A point on the posterior root of the zygomatic arch immediately in front of the orifice of the external acoustic meatus.

Pterion.—The point where the great wing of the sphenoid joins the sphenoidal angle of the parietal; it is situated 35 mm. behind, and 12 mm. above, the level of the frontozygomatic suture.

A line passing through the inferior margin of the orbit and the auricular point is known as *Reid's base-line.*

The right or left half of the *lambdoid suture* is indicated by the upper two-thirds of a line uniting the lambda to the tip of the corresponding mastoid process. The

FIG. 1218.—A drawing of a cast to illustrate the relations of the brain to the skull. (Cunningham.)



sagittal suture is in the line joining the lambda to the bregma. The position of the *coronal suture* is represented by a line connecting the bregma with the centres of the zygomatic arches.

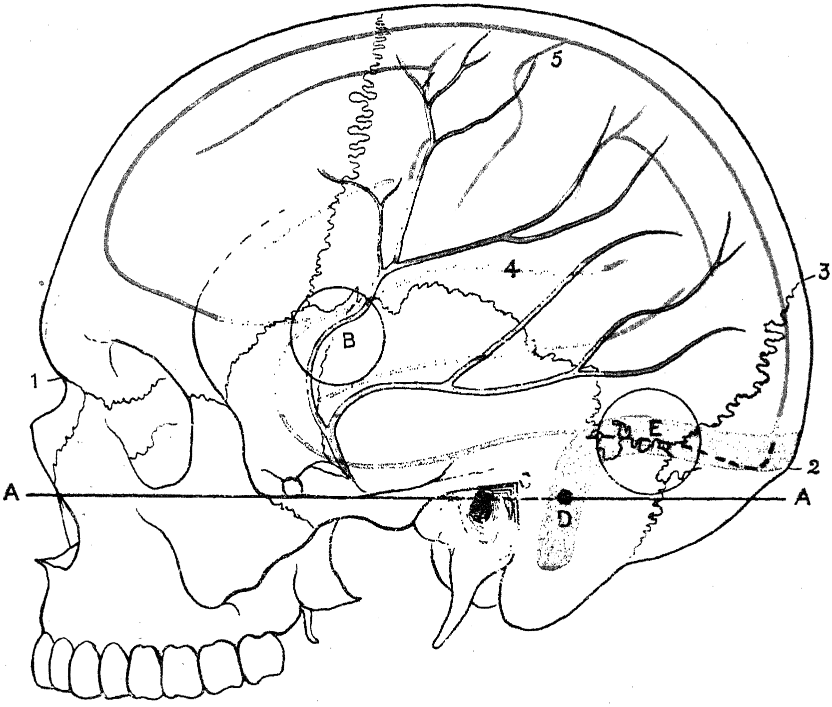
The floor of the middle fossa of the skull is at the level of the posterior three-fourths of the upper border of the zygomatic arch; the articular tubercle of the temporal bone is opposite the foramen spinosum and the semilunar ganglion.

The **brain** (figs. 1218, 1219).—The general outline of the *cerebral hemisphere*, on either side, may be mapped out on the surface in the following manner. A line drawn from the nasion along the middle of the scalp to the inion represents the superomedial border. The line of the posterior part of the lower border is that of the transverse sinus (p. 1264), or more roughly a line convex upwards from the inion to the posterior root of the zygomatic process of the temporal bone; thence along the posterior three-fourths of the upper border of the zygomatic arch and then upwards to the pterion; the anterior part of the lower border extends from

the pterion to the glabella about 1 cm. above the supra-orbital margin. The *cerebellum* is so deeply situated that there is no satisfactory surface marking for it; a point 4 cm. behind and 1·5 cm. below the level of the auricular point is situated directly over it.

The relations of the principal fissures and gyri of the cerebral hemispheres to the surface of the scalp are of practical importance, and several methods of indicating them have been devised. These methods are only approximately correct, but are sufficiently accurate for surgical purposes. The *longitudinal fissure* corresponds to the median line of the scalp between the nasion and inion.

FIG. 1219.—The relations of the brain and the middle meningeal artery to the surface of the skull.



1. Nasion. 2. Inion. 3. Lambda. 4. Lateral cerebral fissure. 5. Central sulcus. AA. Reid's base-line. B. Point for trephining over the anterior branch of the middle meningeal artery. C. Suprameatal triangle. D. Sigmoid bend of the transverse sinus. E. Point for trephining over the straight portion of the transverse sinus, exposing dura mater of both cerebrum and cerebellum. The outline of the cerebral hemisphere is indicated in blue; the course of middle meningeal artery in red.

To mark out the *lateral cerebral* (*Sylvian*) *fissure* a point, named the Sylvian point, is defined 35 mm. behind and 12 mm. above the level of the frontozygomatic suture, the latter being recognised by a notch in its posterior border; the Sylvian point marks the spot where the stem of the lateral cerebral fissure divides. Another method of defining the Sylvian point is to divide the distance between the nasion and inion into four equal parts; from the junction of the third with the fourth part (reckoning from the front) draw a line to the frontozygomatic suture; from the junction of the first with the second part another line to the auricular point. These two lines intersect at the Sylvian point, and the portion of the first line behind this point overlies the posterior ramus of the lateral cerebral fissure. The position of the posterior ramus can also be obtained by joining the Sylvian point to a point 2 cm. below the summit of the parietal tuberosity. The anterior ascending ramus is marked by drawing a line upwards at right angles to the line of the posterior ramus for 2 cm., and the anterior horizontal ramus by a line of the same length drawn horizontally forwards —both from the Sylvian point. The upper end of the *central sulcus* (fissure of Rolando) is in the median line of the skull 1·25 cm. behind the middle of the line

joining the nasion and inion; the lower end is 5 cm. vertically above the pre-auricular point, the fissure ending just above the posterior ramus of the lateral cerebral fissure. Measured on the scalp this line is 9 cm. long and forms an angle, opening forwards, of about 70° with the median line of the scalp. The *precentral* and *postcentral sulci* are nearly parallel with the central sulcus, and are situated about 15 mm. in front of, and behind, it respectively. The *superior frontal sulcus* is indicated by a line drawn from the junction of the upper with the middle one-third of the precentral sulcus, in a direction parallel with the longitudinal sulcus, to a point midway between the middle line of the forehead and the temporal line, 4 cm. above the supra-orbital notch. The *inferior frontal sulcus* begins at the junction of the middle with the lower one-third of the precentral sulcus, and follows the course of the superior temporal line.

The horizontal limb of the *intraparietal sulcus* begins near the junction of the lower with the middle one-third of the postcentral sulcus and curves backwards parallel to the longitudinal fissure, midway between it and the parietal tuberosity; it then curves downwards to end midway between the lambda and the parietal tuberosity. The external part of the *parieto-occipital fissure* runs lateralwards at right angles to the longitudinal fissure for about 2·5 cm. from a point 5 mm. in front of the lambda. If the line of the posterior ramus of the lateral cerebral fissure be continued back to the longitudinal fissure, the last 2·5 cm. of it will indicate the position of the parieto-occipital fissure.

The *lateral ventricle* may be circumscribed by a quadrilateral figure. The upper limit is a horizontal line 5 cm. above the zygomatic arch; this defines the roof of the ventricle. The lower limit is a horizontal line 1 cm. above the zygomatic arch; it indicates the level of the end of the inferior cornu. Two vertical lines, one through the junction of the anterior with the middle one-third of the zygomatic arch, and the other 5 cm. behind the tip of the mastoid process, indicate the extent of the anterior cornu in front and the posterior cornu behind.

The **vessels.**—The *middle meningeal artery* divides into its anterior and posterior branches at a point about 2 cm. above the middle of the upper border of the zygomatic arch. Its anterior branch crosses the great wing of the sphenoidal bone, and then lies in a groove or canal on the inner surface of the sphenoidal angle of the parietal bone at a point 4 cm. behind the frontozygomatic suture and 4·5 cm. above the zygomatic arch. The posterior branch runs backwards less than a finger's breadth above the zygomatic arch, and can be reached 2·5 cm. above the auricular point.

The position of the *transverse sinus* is obtained by taking two lines: the first from the inion to a point 2·5 cm. behind the auricular point; the second from this latter point to the tip of the mastoid process. The second line corresponds roughly to that of the reflection of the skin from the cranial surface of the auricula, and its upper two-thirds represents the sigmoid part of the sinus. The first part of the sinus has a slight upward convexity, and its highest point is about 4 cm. behind and 1 cm. above the level of the auricular point. The width of the sinus is about 1 cm.

The Face

The **air-sinuses** (fig. 1220).—The frontal and maxillary air-sinuses vary so greatly in form and size that their surface markings must be regarded as only approximate. To mark out the position of the *frontal air-sinus* three points are taken: one at the nasion, a second in the middle line 3 cm. above the nasion, and a third at the junction of the lateral with the intermediate one-third of the supra-orbital margin. By joining these a triangular field is described which overlies the greater part of the air-sinus. The outline of the *maxillary air-sinus* is irregularly quadrilateral and is obtained by joining up the following points: (1) the lacrimal tubercle, (2) a point on the zygomatic bone at the junction of the inferior with the lateral margin of the orbit, (3) and (4) points on the alveolar process above the last molar and the second premolar teeth respectively.

The **external maxillary artery.**—The course of the *external maxillary artery* on the face may be indicated by a line starting from the lower border of the mandible at the anterior margin of the Masseter, and running at first forwards and upwards to a point 1 cm. lateral to the angle of the mouth, thence to a point a little behind the ala of the nose and upwards to the medial commissure of the eye (fig. 1221).

The **trigeminal nerve.**—The *supratrochlear nerve* crosses the supra-orbital margin about 1 cm. from the middle line. The *supra-orbital, infra-orbital,* and *mental nerves* emerge from the corresponding foramina on the face (fig. 1221). The supra-orbital foramen is situated at the junction of the medial with the intermediate third of the supra-orbital margin. A line drawn from this foramen to the lower border of the mandible, through the interval between the lower premolar teeth, passes over the infra-orbital and mental foramina: the former lies about 1 cm. below the margin of the orbit, while the latter varies in position according to the age of the individual; in the adult it is midway between the upper and lower borders of the mandible, in the child it is nearer the lower border, while in the edentulous jaw of old age it is close to the upper margin.

FIG. 1220.—An outline of the bones of the face, showing the positions of the frontal and maxillary air-sinuses.

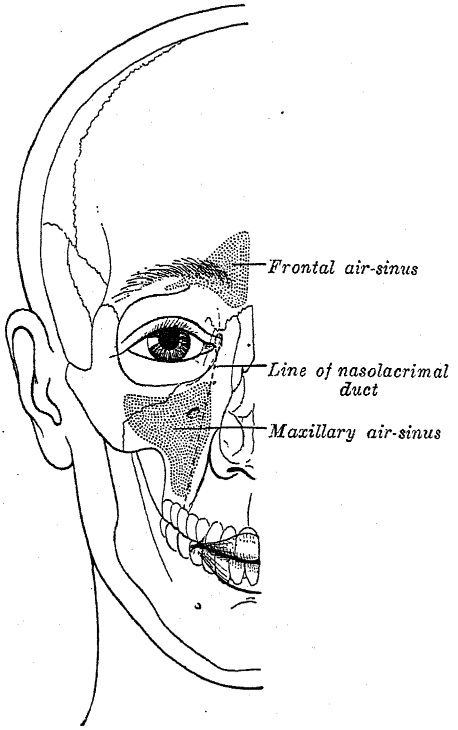
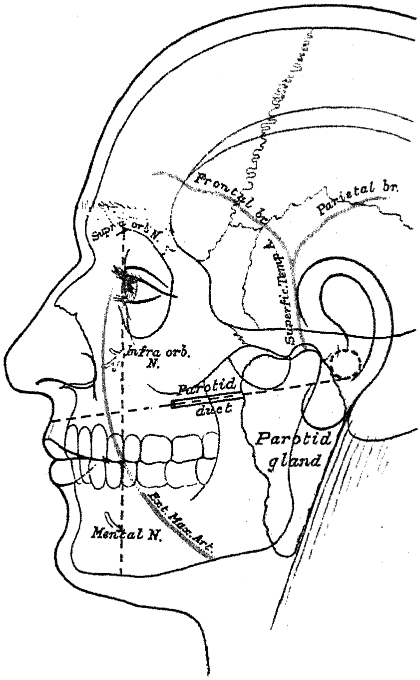


FIG. 1221.—An outline of the side of the face, showing the chief surface markings.



The position of the *sphenopalatine ganglion* is indicated from the side by a point on the upper border of the zygomatic arch, 6 mm. from the temporal border of the zygomatic bone. The foramen ovale, which is the guide to the *semilunar ganglion,* lies opposite the anterior border of the neck of the mandible.

The **parotid gland** (fig. 1221).—The upper border of the parotid gland corresponds to the posterior two-thirds of the lower border of the zygomatic arch; the posterior border to the front of the external acoustic meatus, the mastoid process, and the anterior border of Sternocleidomastoideus. The inferior border is indicated by a line from the tip of the mastoid process to the junction of the body and greater cornu of the hyoid bone. In front, the anterior border extends for a variable distance on the superficial surface of the Masseter. The surface marking for the *parotid duct* is the middle one-third of a line drawn across the face about a finger's breadth below the zygomatic arch, i.e. from the lower margin of the concha to midway between the red margin of the lip and the ala of the nose; the duct ends opposite the second upper molar tooth and measures about 5 cm. in length.

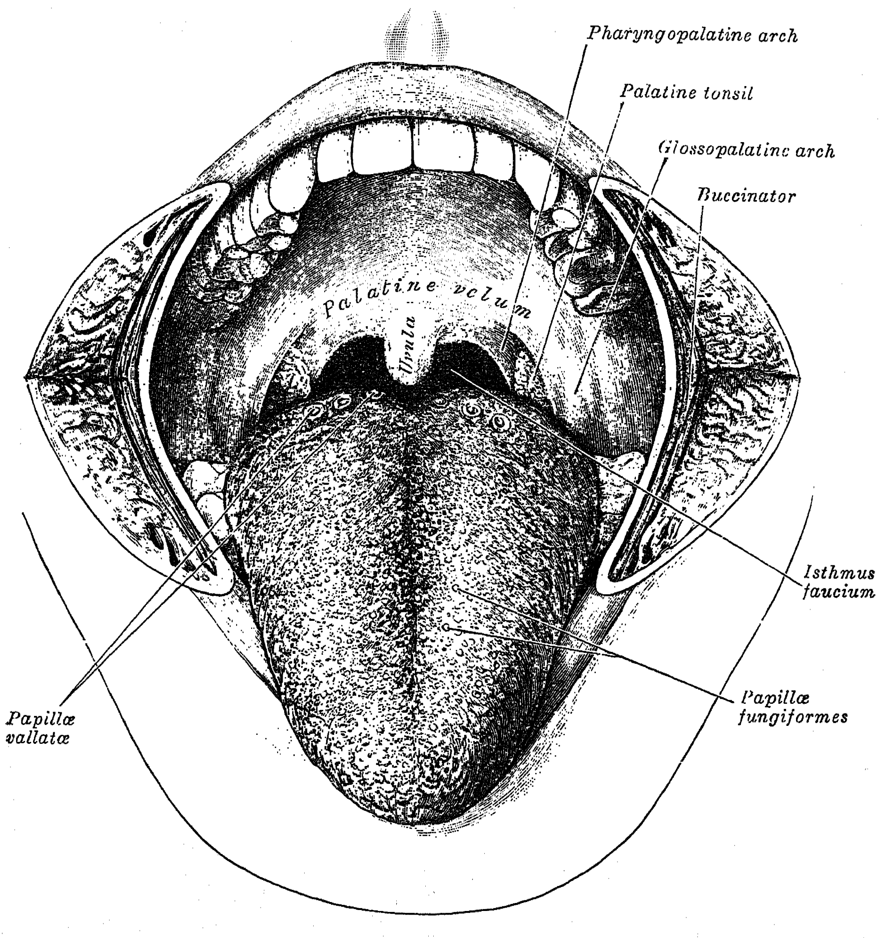
The Nose

The outlines of the nasal bones and the cartilages forming the external nose can be easily felt. The mobile portion of the nasal septum, formed by the medial crura of the greater alar cartilages and the skin, is easily distinguished between the nares. When the head is tilted back and a speculum introduced through one naris, the floor of the nasal cavity, the lower part of the nasal septum, and the anterior ends of the middle and inferior nasal conchæ can be examined. The opening of the nasolacrimal duct, which lies under cover of the front of the inferior nasal concha, is situated about 2·5 cm. behind the naris and 2 cm. above the floor of the nasal cavity.

The Mouth

The orifice of the mouth is bounded by the lips, and its angles usually correspond to the lateral borders of the canine teeth. In the middle of the outer surface of the upper lip is a shallow groove—the philtrum. When the lips are everted, a small fold

Fig. 1222.—The mouth-cavity. The cheeks have been slit transversely and the tongue pulled forwards.



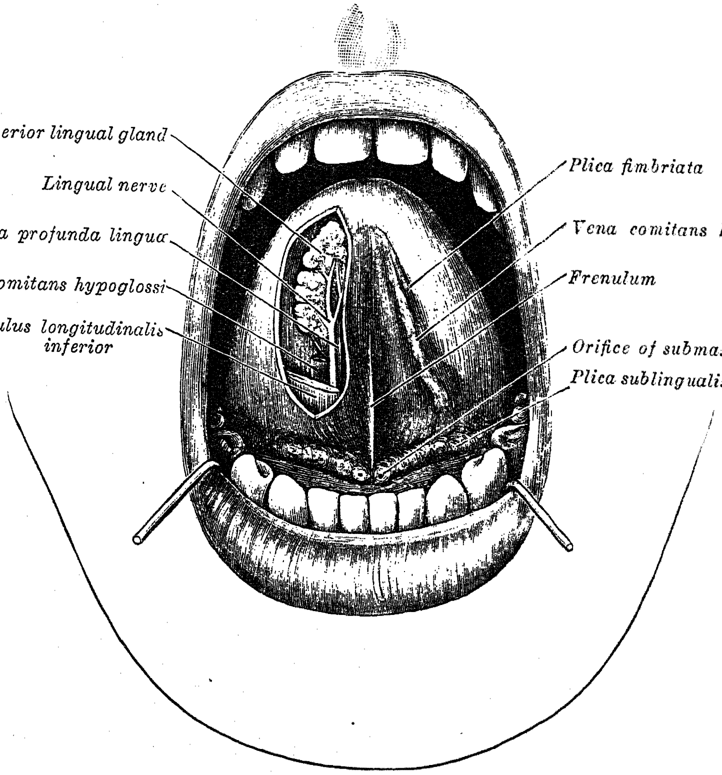
of mucous membrane, termed the frenulum, is seen in the middle line of each, passing from the lip to the gum. By pulling the angle of the mouth outwards the mucous membrane of the cheek can be inspected, and on this, opposite the second upper molar tooth, is the little papilla which marks the orifice of the parotid duct.

The upper surface of the tongue (fig. 1222) is convex and marked in the middle line by a shallow sulcus ; its anterior two-thirds are rough and studded with papillæ ;

its posterior one-third is smoother and contains many muciparous glands and lymph-follicles; it is much more sensitive than the anterior papillary part. These two parts are separated by a V-shaped furrow, the sulcus terminalis, which is situated immediately behind the papillæ vallatæ.

The mucous membrane on the under surface of the tongue (fig. 1223) is smooth and devoid of papillæ. In the middle line it extends to the floor of the mouth as a fold—the frenulum—the free edge of which runs forwards to the symphysis of the mandible. The *lingual veins* are seen immediately beneath the mucous membrane on either side of the frenulum. On either side of the attachment of the

Fig. 1223.—The mouth-cavity. The apex of the tongue is turned upwards, and on the right side a superficial dissection of its under surface has been made.



frenulum to the floor of the mouth is a papilla on which the slit-like orifice of the submaxillary duct is seen. Running backwards and lateralwards from the orifice of the submaxillary duct is the plica sublingualis, produced by the upward projection of the sublingual gland which lies immediately beneath the mucous membrane. The plica sublingualis serves also to indicate the lines of the submaxillary duct and lingual nerve; they lie on the medial side of the sublingual gland. At the back of the mouth is the isthmus faucium, bounded above by the palatine velum, from the free margin of which the uvula projects downwards in the middle line. On either side of the isthmus are the two palatine arches, the anterior formed by the Glossopalatinus and the posterior by the Pharyngopalatinus. Between the two arches of either side is the palatine tonsil, with the small supratonsillar recess above it; the position of the tonsil corresponds to the angle of the mandible. When the mouth is opened widely, a tense band—the pterygomandibular raphe—can be seen and felt lateral to the glossopalatine arch. Its lower end is attached to the mandible behind the last molar tooth, and immediately below and in front of this attachment the lingual nerve can be felt; the upper end of the raphe is fixed to the pterygoid hamulus. About 1 cm. anterior to the hamulus and 1 cm.

medial to the third upper molar tooth is the greater palatine foramen through which the greater palatine vessels and the anterior palatine nerve emerge. Behind the third upper molar tooth the coronoid process of the mandible is palpable.

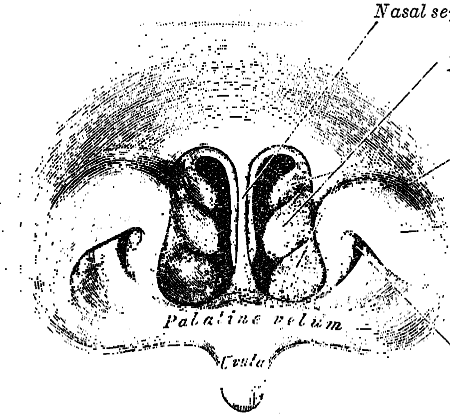
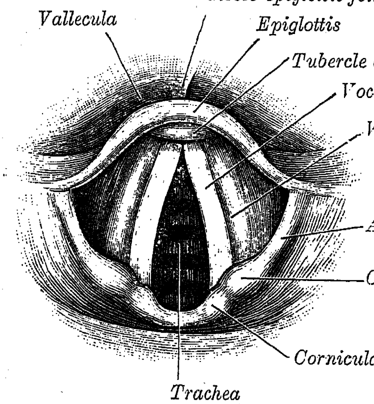


FIG. 1224.—The front of the nasal part of the pharynx, as seen with the laryngoscope.

By tilting the head well back a portion of the posterior pharyngeal wall corresponding to the level of the second and third cervical vertebræ, can be seen through the isthmus faucium. On introducing the finger the anterior surfaces of the upper cervical vertebræ can be felt through the thin muscular wall of the pharynx; if the finger be hooked round the palatine velum, the choanæ, the posterior ends of the middle and inferior nasal conchæ, and the pharyngeal ostia of the auditory (Eustachian) tubes can be distinguished. The level of the choanæ is that of the atlas, while the palatine velum is opposite the body of the epistropheus.

FIG. 1225.—A laryngoscopic view of the interior of the larynx.

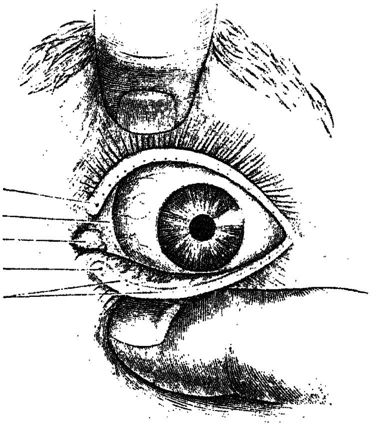


With the laryngoscope the following structures can be seen. In the nasal part of the pharynx (fig. 1224), the choanæ, the nasal septum and conchæ, and the pharyngeal ostia of the auditory tubes can be examined. Farther down are the pharyngeal part of the dorsum of the tongue, the anterior surface of the epiglottis with the glosso-epiglottic and pharyngo-epiglottic folds bounding the valleculæ, and the pyriform recesses. Beyond these is the entrance to the larynx, bounded on either side by the aryepiglottic folds, in each of which are two rounded eminences corresponding to the corniculate and cuneiform cartilages. Within the larynx (fig. 1225) on either side are the ventricular and vocal folds (false and true vocal cords) with the ventricle of the larynx between them. Still deeper, the cricoid cartilage and the anterior parts of some of the cartilaginous rings of the trachea are visible, and sometimes, during deep inspiration, the bifurcation of the trachea. Further investigation of the interior of the lower part of the trachea and the upper parts of the bronchi can be carried out with the bronchoscope.

The Eye

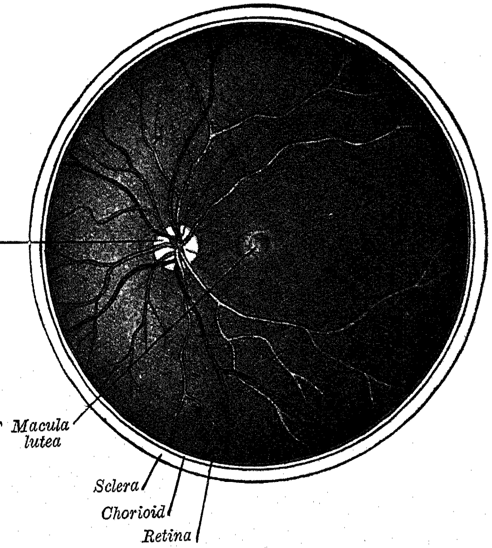
The palpebral fissure is elliptical in shape, and varies in form and size in different individuals and in different races of mankind; normally it is oblique, in a direction upwards and lateralwards, so that the lateral commissure is on a slightly higher level than the medial. When the eyes are directed forward as in ordinary vision, the superior part of the cornea is covered by the upper eyelid and its inferior margin is on a level with the free margin of the lower eyelid.

Fig. 1226.—The front of the left eye with the eyelids separated to show the structures at the medial commissure.



At the medial commissure (fig. 1226) are the caruncula lacrimalis and the plica semilunaris. When the lids are everted, the tarsal glands appear as a series of vertical parallel rows of light yellow granules. On the margins of the lids about 5 mm. from the medial commissure are the puncta lacrimalia; in the natural condition they are in contact with the conjunctiva of the bulb of the eye, so that it is necessary to evert the eyelids to expose them. The lacrimal sac lies immediately above and medial to a small tubercle which can be plainly felt on the inner part of the lower margin of the orbit. If the eyelids be drawn lateralwards the medial palpebral ligament (tendo oculi) can be felt beneath the tightened skin at the medial commissure; it crosses in front of and a little above the middle of the lacrimal sac, and forms a useful guide to it. The direction of the naso-lacrimal duct is indicated by a line from the lacrimal sac to the first upper molar tooth; the length of the duct is about 18 mm.

Fig. 1227.—The interior of the posterior half of the left eyeball.



The veins are darker in appearance than the arteries.

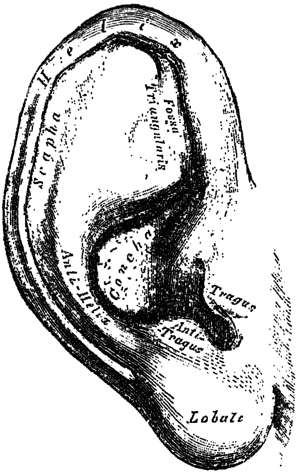
On looking into the eye, the iris with its opening, the pupil, and the front of the lens can be examined, but for investigation of the retina an ophthalmoscope is necessary. With this instrument the lens, the vessels of the retina, the optic disc, and the macula lutea can all be inspected (fig. 1227).

On the lateral surface of the nasal part of the frontal bone the pulley of the Obliquus superior can be easily reached by pushing the finger backwards along the roof of the orbit; the tendon of the muscle can be traced for a short distance backwards and lateralwards from the pulley.

The Ear

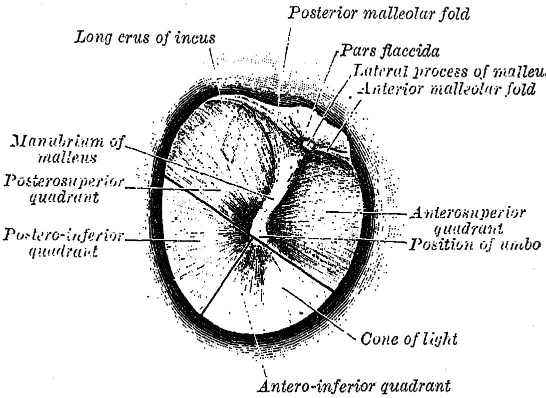
The various prominences and fossæ of the auricula (pp. 1022 to 1023) are visible (fig. 1228). The orifice of the external acoustic meatus is exposed by drawing the tragus forwards; at the orifice are a few short crisp hairs which serve to prevent the entrance of dust or of small insects; beyond this the secretion of the ceruminous glands serves to catch any small particles which may find their way into the meatus. The interior of the meatus can be examined through a speculum. At the junction of its bony and cartilaginous portions is an obtuse angle which projects into the antero-inferior wall and produces a narrowing of the lumen. The cartilaginous part, however, is connected to the bony part by fibrous tissue only; this renders the outer portion of the meatus very movable. By drawing the auricula upwards, backwards, and slightly outwards, the cartilaginous portion of the canal is straightened. In children the meatus is very short, and this should be remembered in introducing a speculum.

Fig. 1228.—The auricula or pinna. Lateral surface.



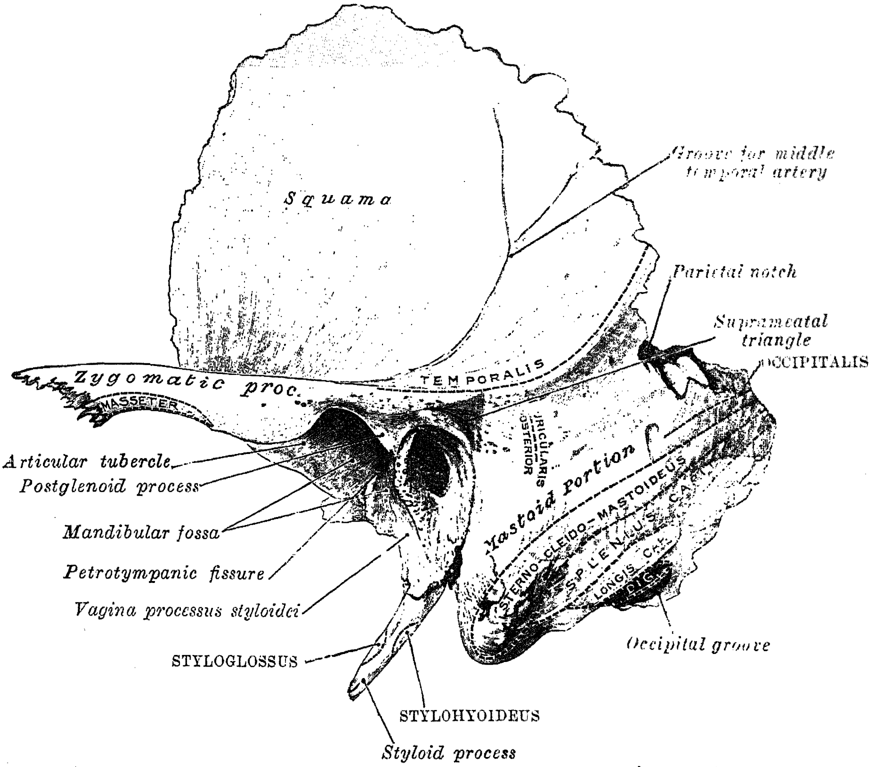
Through the speculum the greater part of the tympanic membrane (fig. 1229) is visible. It is a pearly-grey, slightly glistening membrane; in the adult it is placed obliquely so as to form an angle of about fifty-five degrees with the floor and with the anterior wall of the meatus; at birth it is more horizontal and situated in almost the same plane as the base of the skull. The membrane is concave outwards, and the point of deepest concavity is a little below the centre. Running upwards and slightly forwards from this point is a reddish-yellow streak produced by the manubrium of the malleus. This streak ends above near the roof of the meatus at a small white rounded prominence which is caused by the lateral process of the malleus projecting against the membrane. The anterior and posterior malleolar folds extend from the prominence to the circumference of the membrane and form the lower boundary of the pars flaccida of the membrane. Behind the streak caused by the manubrium of the malleus a shorter and fainter streak can sometimes be distinguished; this is the long crus of the incus. A narrow triangular patch extending downwards and forwards from the lower end of the manubrium mallei reflects the light more brightly than any other part, and is usually described as the cone of light.

Fig. 1229.—The right tympanic membrane, as seen through a speculum.



The **tympanic antrum.**—The site of the tympanic antrum is indicated by the suprameatal triangle (fig. 1230) which is bounded above by the posterior root of the zygomatic arch, behind by a vertical line from the posterior border of the orifice of the bony external acoustic meatus, in front and below by the upper margin of the orifice.

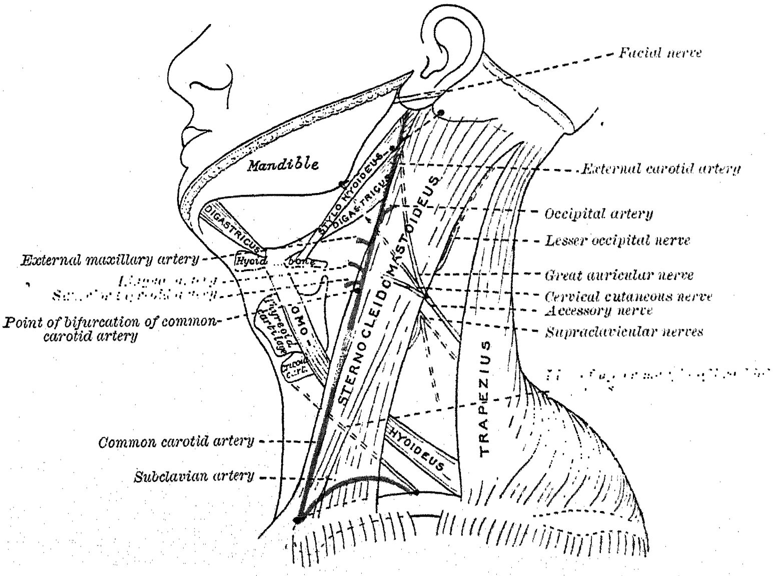
FIG. 1230.—The left temporal bone showing the surface markings for the tympanic antrum (red), the transverse sinus (blue), and the facial nerve (yellow).



THE NECK (fig. 1231)

The **muscles.**—The posterior belly of the *Digastricus* is marked out by a line from the tip of the mastoid process to the junction of the greater cornu and body

FIG. 1231.—The side of the neck, showing the chief surface markings.



of the hyoid bone; a line from this latter point to one just lateral to the symphysis of the mandible indicates the position of the anterior belly. The line of the *Omohyoideus* begins at the lower border of the body of the hyoid bone, runs downwards and lateralwards to reach the anterior border of the Sternocleidomastoideus at the level of the cricoid cartilage, and then runs more horizontally to the acromial end of the clavicle.

The **arteries.**—The position of the *common carotid artery* in the neck is indicated by a line drawn from the upper part of the sternal end of the clavicle to a point midway between the tip of the mastoid process and the angle of the mandible. From the clavicle to the upper border of the thyreoid cartilage this line overlies the common carotid artery, beyond this it is over the *external carotid artery.* The external carotid artery may be otherwise marked out by the upper part of a line, arching slightly forwards, from the side of the cricoid cartilage to the front of the orifice of the external acoustic meatus.

The points of origin of the main branches of the external carotid artery are related to the tip of the greater cornu of the hyoid bone as follows: (1) the *superior thyreoid,* just below it; (2) the *lingual,* on a level with it; (3) the *external maxillary* (facial) and (4) the *occipital,* a little above and behind it.

The *subclavian artery* is indicated on the surface by a curved line, convex upwards, from the sternoclavicular articulation to the middle of the clavicle. The highest point of the convexity is about 2 cm. above the clavicle.

The **veins.**—The surface marking for the *internal jugular vein* is parallel with and slightly lateral to that for the common carotid artery; the line indicating it is drawn from the sternal end of the clavicle between the two heads of the Sternocleidomastoideus to a point just behind the angle of the mandible. The *common facial vein* joins the internal jugular vein about the level of the hyoid bone. The position of the *external jugular vein* is marked by a line from the angle of the mandible to the middle of the clavicle. A point on this line about 4 cm. above the clavicle indicates the spot where the vein pierces the deep fascia. The line of the *anterior jugular vein* begins close to the symphysis of the mandible, runs downwards parallel with and a little to one side of the middle line, and, at a short distance above the jugular notch, turns lateralwards to the external jugular.

The **nerves.**—The *facial nerve* at its exit from the stylomastoid foramen is situated, in the adult, about 2·5 cm. from the surface, opposite the middle of the anterior border of the mastoid process; a horizontal line from this point to the ramus of the mandible overlies the stem of the nerve. In the infant there is no mastoid process, and the foramen is placed superficially just behind the orifice of the external acoustic meatus. To mark the course of the *accessory nerve* a line is drawn from a point midway between the angle of the mandible and the tip of the mastoid process to a point on the anterior border of the Sternocleidomastoideus 4 cm. below the apex of the mastoid process; the line is continued across the posterior triangle of the neck to the Trapezius.

The cutaneous branches of the cervical plexus emerge from beneath the posterior border of the Sternocleidomastoideus and may be indicated as follows: the *lesser occipital nerve* appears just above the midpoint of the border and ascends along it to the scalp; the *great auricular* and *cervical cutaneous nerves* start from the middle of the border, the former running upwards towards the lobule of the auricula, the latter crossing the Sternocleidomastoideus at right angles to its long axis; the *supraclavicular nerves* emerge just below the middle of the posterior border and run down over the clavicle. The *phrenic nerve* begins at the level of the middle of the thyreoid cartilage and runs behind the clavicle about midway between the anterior and posterior borders of the Sternocleidomastoideus.

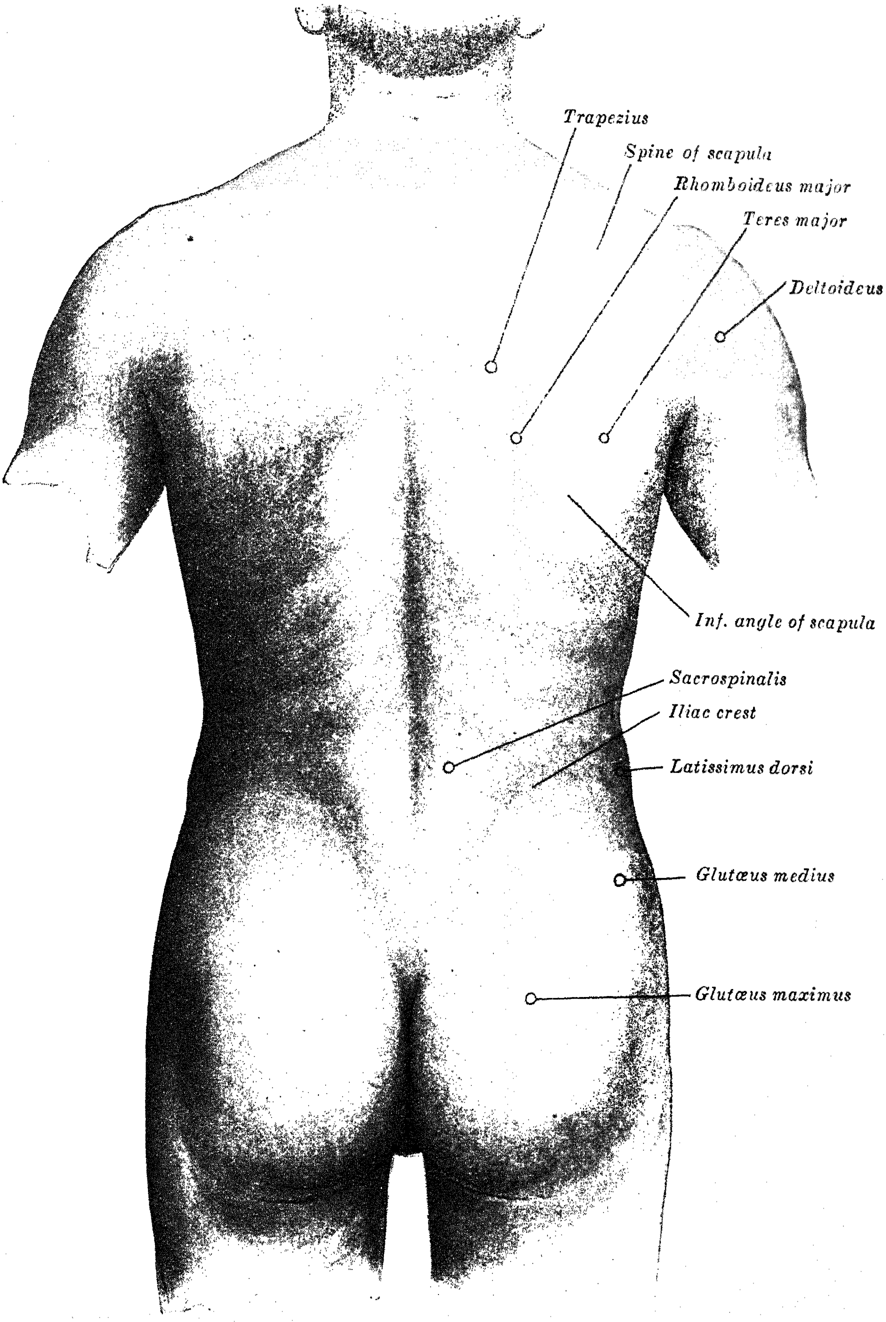
The upper border of the *brachial plexus* is indicated by a line from the side of the cricoid cartilage to the middle of the clavicle; the plexus begins a short distance in front of the posterior border of the Sternocleidomastoideus.

THE SURFACE ANATOMY OF THE BACK

The **bones.**—The only subcutaneous parts of the vertebral column are the apices of the spinous processes. These are distinguishable at the bottom of a furrow which runs down the middle line of the back from the external occipital protuberance

to the middle of the sacrum. In the *cervical region* the furrow is broad and ends below in a conspicuous projection caused by the spinous processes of the seventh

Fig. 1232.—The surface anatomy of the back.



cervical and first thoracic vertebræ. Above this, the spinous process of the sixth cervical vertebra sometimes forms a projection ; the other cervical spinous processes are sunken, but that of the epistropheus can be felt. In the *thoracic region* the furrow is shallow and during stooping disappears, and then the spinous processes become more or less visible ; the markings produced by them are small and close

together. In the *lumbar region* the furrow is deep and the situations of the spinous processes are frequently indicated by little pits, especially when the muscles in the loins are well developed. In the *sacral region* the furrow is shallow and flattened, and ends below at the most prominent part of the dorsal surface of the sacrum, i.e. the spinous process of the third sacral vertebra. At the bottom of the sacral furrow the irregular dorsal surface of the sacrum may be felt, and below this, in the deep groove running to the anus, the coccyx.

The **muscles.**—The deep muscles of the back are so covered by those of the upper extremity (fig. 1232) that they have very little influence on surface form. The *Splenii* by their divergence serve to broaden out the upper part of the back of the neck and produce a fulness in this situation. In the loin the *Sacrospinales*, bound down by the lumbodorsal fascia, form rounded vertical eminences which determine the depth of the spinal furrow and taper below to a point on the dorsal surface of the sacrum. The continuations of the Sacrospinales in the lower thoracic region form flattened planes which are gradually lost on passing upwards.

THE SURFACE MARKINGS OF THE BACK

The **bony landmarks.**—In order to identify any particular spinous process it is customary to count from the prominence caused by the seventh cervical and first thoracic; of these the latter is the more prominent, although the seventh cervical

Fig. 1233.—A diagram showing the relation of the medulla spinalis to the dorsal surface of the trunk. The bones are outlined in red.

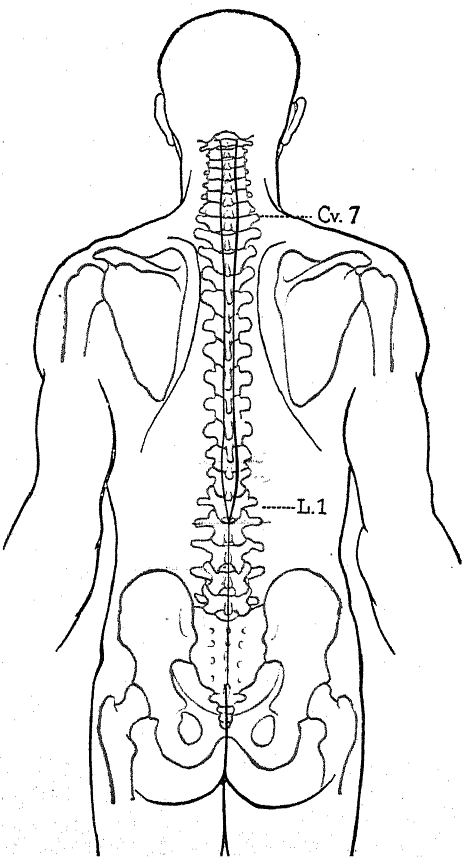
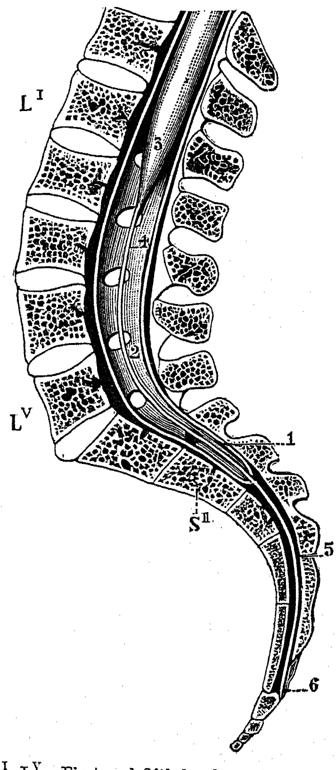


Fig. 1234.—A sagittal section through the lower part of the vertebral canal to show the lower ends of the medulla spinalis and subarachnoid cavity, and the filum terminale. (Testut.)



L^{I}, L^{V}. First and fifth lumbar vertebræ. S^{II}. Second sacral vertebra. 1. Dura mater. 2. Lower part of subarachnoid cavity. 3. Lower extremity of medulla spinalis. 4. Filum terminale internum. 5. Filum terminale externum. 6. Attachment of filum terminale to first segment of coccyx.

is known as the vertebra prominens. The root of the spine of the scapula is on a level with the tip of the spinous process of the third thoracic vertebra, and the inferior angle with that of the seventh. The highest point of the iliac crest is on a level with the spinous process of the fourth lumbar, and the posterior superior iliac spine with that of the second sacral, vertebra.

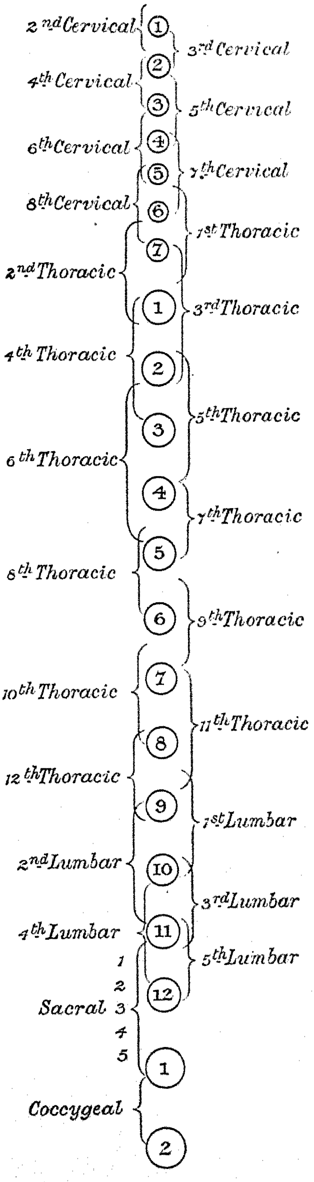
The **medulla spinalis.**—The position of the lower end of the medulla spinalis varies slightly with the movements of the vertebral column, but, in the adult, in the upright posture it is usually at the level of the spinous process of the second lumbar vertebra (fig. 1233); at birth it is at the level of the third.

The *subdural* and *subarachnoid cavities* end opposite the spinous process of the third sacral vertebra (fig. 1234).

The **spinal nerves** (fig. 1235).—The following table, after Macalister, shows the relations which the places of attachment of the nerves to the medulla spinalis bear to the bodies and spinous processes of the vertebræ :—

Level of body of	No. of nerve.	Level of tip of spine of
C. 1	C. 1	..
	2	..
2	3	1 C.
3	4	2
4	5	3
5	6	4
6	7	5
..	8	6
7	T. 1	7
T. 1	2	1 T.
2	3	..
3	4	2
4	5	3
5	6	4
6	7	5
7	8	6
8	9	7
9	10	8
10	11	9
..	12	10
11	L. 1	11
..	2	..
12	3	..
..	4	12
	5	
	S. 1	..
L. 1	2	
	3	
	4	1 L.
	5	
	C. 1	
L. 2	..	..

FIG. 1235.—A scheme showing the relations of the vertebral spinous processes to the regions of attachment of the spinal nerves. (After Reid.)

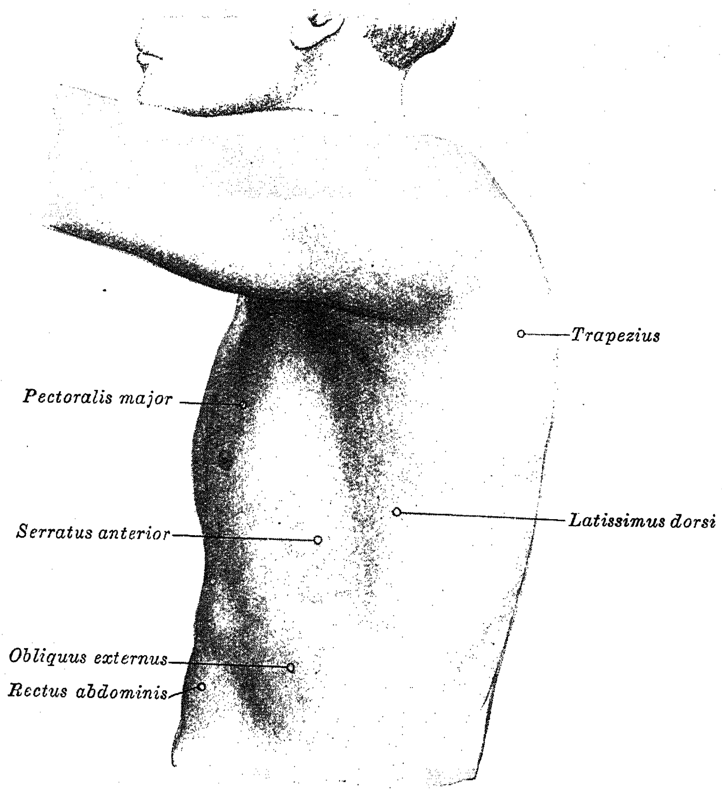


THE SURFACE ANATOMY OF THE THORAX

The **bones.**—The skeleton of the thorax is covered to a considerable extent by muscles, so that in a strongly developed muscular subject it is for the most part concealed. In thin persons the *ribs*, especially in the lower and lateral regions, stand out as prominent ridges between the sunken intercostal spaces.

In the middle line, in front, the anterior surface of the *sternum* can be felt throughout its entire length at the bottom of the sternal furrow, between the Pectorales majores. These muscles overlap the anterior surface somewhat, so

Fig. 1236.—The left side of the thorax.



that the whole width of the sternum is not subcutaneous, and this overlapping is greatest opposite the middle of the bone; the sternal furrow, therefore, is wide at its upper and lower parts but narrow in the middle. At the upper border of the manubrium sterni is the *jugular notch*: the lateral parts of this notch are obscured by the tendinous origins of the Sternocleidomastoidei, which appear as oblique cords narrowing and deepening the notch. At the junction of the manubrium and body is a transverse ridge, the *sternal angle* (angulus Ludovici). From the middle of the sternum the sternal furrow widens, and ends at the junction of the body of the sternum with the xiphoid process. Immediately below this is the *infrasternal notch*; between the sternal ends of the seventh costal cartilages, and below the notch, is a triangular depression, the epigastric fossa, in which the *xiphoid process* can be felt.

On either side of the sternum the costal cartilages and ribs on the front of the thorax are partially obscured by the Pectoralis major, through which, however, they can be felt as ridges with yielding intervals between them corresponding to the intercostal spaces. The second space is the widest, the third and fourth

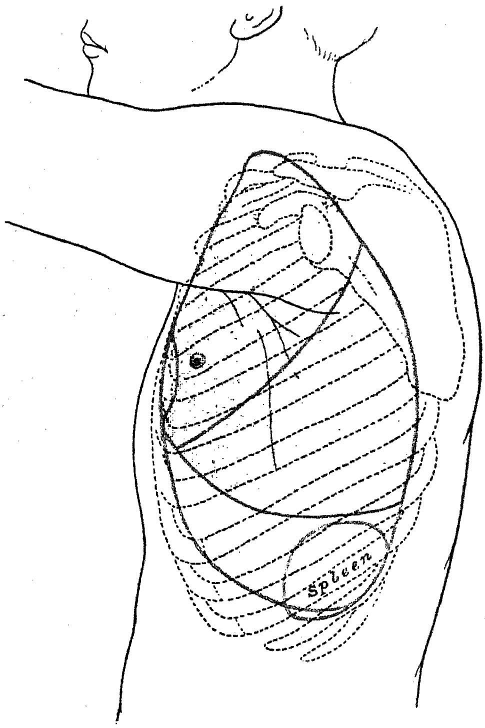
are somewhat narrower, and the others, with the exception of the last two, are comparatively narrow.

Below the lower border of the Pectoralis major on the front of the chest, the broad flat outlines of the ribs, and the more rounded outlines of the costal cartilages, are often visible. The lower boundary of the front of the thorax is most plainly seen when the body is bent backwards; it is formed by the xiphoid process, the cartilages of the seventh, eighth, ninth, and tenth ribs, and the ends of the cartilages of the eleventh and twelfth ribs.

On either side of the thorax, from the axilla downwards, the external surfaces of the ribs may be defined. Although covered by muscles, all the ribs, with the exception of the first, can generally be followed without difficulty over the front and sides of the thorax. The first rib, being almost completely covered by the clavicle, can only be distinguished in a small portion of its extent.

At the back, the angles of the ribs lie on slightly marked oblique lines some distance from the spinous processes of the vertebræ. The lines diverge somewhat as they descend, and lateral to each line is a broad convex surface caused by the projection of the ribs beyond their angles. Over this surface, except where covered by the scapula, the individual ribs can be distinguished.

Fig. 1237.—The side of the thorax, showing the surface markings for the bones, lung (purple), pleura (blue), and spleen (green).



The **muscles**.—The surface muscles covering the thorax belong to the musculature of the upper extremity (figs. 1236, 1240), and will be described in that section (p. 1295). There is, however, an area of practical importance bounded by these muscles. It is limited above by the lower border of the Trapezius, below by the upper border of the Latissimus dorsi, and laterally by the vertebral border of the scapula; the floor is partly formed by the Rhomboideus major. If the trunk be flexed, and the scapula drawn forwards by folding the arms across the chest, parts of the sixth and seventh ribs and the interspace between them become subcutaneous and available for auscultation. The space is therefore known as the *triangle of auscultation*.

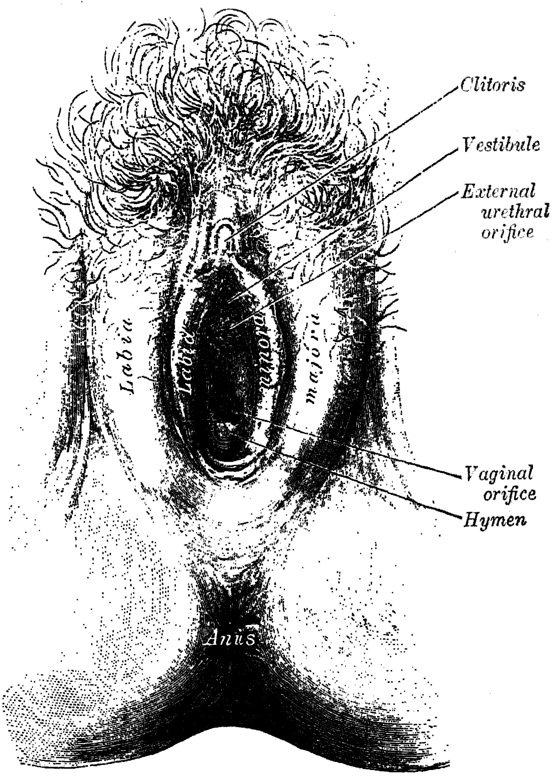
The **mamma**.—The size of the mamma is subject to great variations. In the adult nulliparous female it extends vertically from the second to the sixth rib, and transversely from the side of the sternum to the midaxillary line. In the male and in the nulliparous female the *mammary papilla* or *nipple* is situated in the fourth interspace about 9 or 10 cm. from the middle line.

THE SURFACE MARKINGS OF THE THORAX

The **bony landmarks**.—The second costal cartilage is on a level with the sternal angle, and is so readily found that it is used as a starting-point from which to count the ribs. The lower border of the Pectoralis major at its origin corresponds to the fifth rib; the uppermost visible digitation of the Serratus anterior indicates the sixth rib.

majora, and extending from the clitoris obliquely downwards, lateralwards, and backwards for about 4 cm. on either side of the orifice of the vagina, between which and the labia majora they end; in the virgin the posterior ends of the labia minora are usually joined across the middle line by a fold of skin, named the *frenulum of the labia*, or *fourchette*. Anteriorly, each labium minus divides into two portions: the upper division passes above the clitoris to meet its fellow of the opposite side, forming a fold which overhangs the glans clitoridis, and is named the *præputium clitoridis*; the lower division passes beneath the clitoris and is united to its under surface, forming, with its fellow of the opposite side, the *frenulum clitoridis*. On the opposed surfaces of the labia minora are numerous sebaceous follicles.

FIG. 1194.—The external genital organs of the female. The labia have been drawn apart.



The **vestibule**.—The cleft between the labia minora is named the *vestibule of the vagina*: in it are the vaginal and external urethral orifices and the openings of the ducts of the greater vestibular glands. The part of the vestibule between the vaginal orifice and the frenulum of the labia minora consists of a shallow depression named the *navicular fossa*.

The **clitoris** is an erectile structure, homologous with the penis. It is situated beneath the anterior labial commissure, partially hidden between the anterior ends of the labia minora. The *body of the clitoris* (corpus clitoridis) consists of two corpora cavernosa, composed of erectile tissue enclosed in a dense layer of fibrous membrane, and separated along their medial surfaces by an incomplete fibrous pectiniform septum; each corpus cavernosum is connected to the pubic and ischial rami by a *crus*. The free extremity, or *glans clitoridis*, is a small rounded tubercle, consisting of spongy erectile tissue, and highly sensitive. The clitoris is provided, like the penis, with a suspensory ligament, and with two small muscles, the Ischiocavernosi, which are inserted into the crura of the clitoris.

The **vaginal orifice** is a median slit below and behind the opening of the urethra; its size varies inversely with that of the *hymen*.

The **hymen** is a thin fold of mucous membrane situated at the orifice of the vagina; the inner surfaces of the fold are normally in contact with each other, and the vaginal orifice appears as a cleft between them. The hymen varies much in shape. When stretched, its commonest form is that of a ring, generally broadest posteriorly; sometimes it is represented by a semilunar fold, with its concave margin turned towards the pubes. Occasionally it is cribriform, or its free margin forms a membranous fringe. It may be entirely absent, or may form a complete septum across the lower end of the vagina; the latter condition is known as an imperforate hymen. When the hymen has been ruptured, small rounded elevations known as the *carunculæ hymenales* are found as its remains.

junction between the manubrium and body of the sternum. It follows the midsternal line to the lower end of the body of the sternum or on to the xiphoid process, and then turns lateralwards and downwards across the seventh sternocostal articulation. It crosses the eighth costochondral junction in the mammary line, the tenth rib in the midaxillary line, and is prolonged thence to the spinous process of the twelfth thoracic vertebra, to reach which it passes below the level of the medial part of the twelfth rib. The most dependent part of the pleural cavity is opposite the tenth rib in the midaxillary line.

On the *left* side the line passes through the sternoclavicular articulation, reaches the midpoint of the junction between the manubrium and body of the sternum, and extends down the midsternal line to the level of the fourth costal cartilage. It then inclines to the left and is continued downwards as far as the sixth costal cartilage; it is situated at a variable distance from the midsternal line; frequently it is behind the sternum all the way down, or it may be as much as 1·25 cm. from the side of the sternum. Running downwards and lateralwards from the sixth costal cartilage it crosses the seventh costal cartilage, and from this onwards it is similar to the line on the right side but at a slightly lower level.

The **lungs** (figs. 1237, 1238).—The *apex* of the lung is situated in the neck above the medial one-third of the clavicle. The average height to which it rises above the clavicle is about 2·5 cm.

In order to mark out the *anterior borders* of the lungs two lines, one from each apex, are drawn downwards and medialwards across the sternoclavicular articulation and manubrium sterni until they meet, or almost meet, at the midpoint of the sternal angle. From this point the two lines run downwards, in the midsternal line, as far as the level of the fourth costal cartilages. On the *right* side the line is continued in the midsternal line to the level of the sixth costal cartilage, and then it turns lateralwards and downwards. On the *left* side the line curves lateralwards and downwards across the fourth sternocostal articulation to reach the parasternal line at the fifth costal cartilage, and then turns medialwards and downwards to the sixth sternocostal articulation.

In the position of expiration the *lower border* of the lung may be marked by a line slightly curved with its convexity downwards, from the sixth sternocostal junction to the tenth thoracic spinous process. This line crosses the mammary line at the sixth, the midaxillary line at the eighth, and the scapular line at the tenth rib.

The *posterior borders* of the lungs are indicated by lines drawn from the level of the spinous process of the seventh cervical vertebra, down either side of the vertebral column, across the costovertebral joints, as low as the spinous process of the tenth thoracic vertebra.

The position of the *oblique fissure* in either lung can be shown by a line drawn from the spinous process of the second thoracic vertebra round the side of the thorax to the sixth rib in the mammary line; this line corresponds roughly to that of the vertebral border of the scapula when the hand is placed on the top of the head. The *horizontal fissure* in the right lung is indicated by an almost horizontal line drawn from the midsternal line at the level of the fourth costal cartilage to the point where the oblique fissure cuts the midaxillary line.

The *roots* of the lungs are placed opposite the spinous processes of the fourth, fifth and sixth thoracic vertebræ, i.e. they extend from just below the root of the spine of the scapula, almost to the inferior angle of the scapula.

The **trachea.**—The course of the trachea may be marked out on the back by a line from the spinous process of the sixth cervical to that of the fourth thoracic vertebra; at the latter level the trachea bifurcates, and from its bifurcation the two bronchi are directed downwards and lateralwards. Anteriorly, the point of bifurcation is opposite to or a little below the sternal angle.

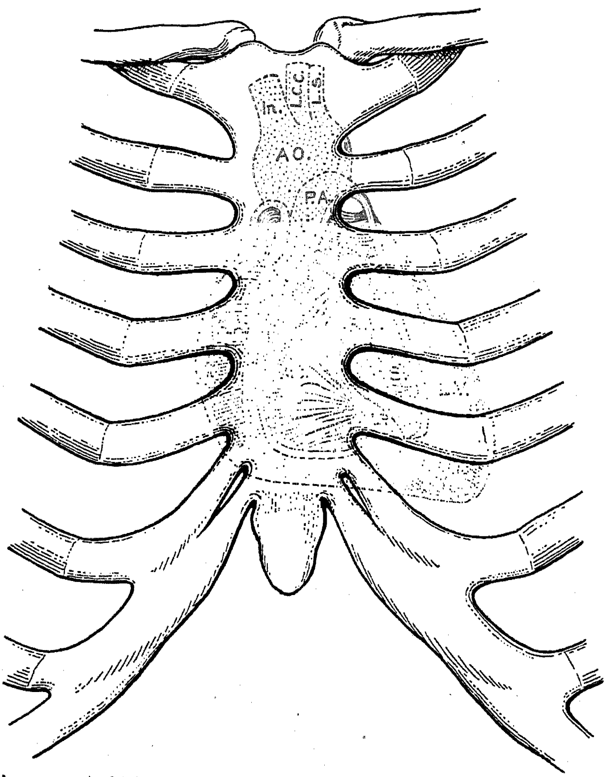
The **œsophagus.**—The extent of the œsophagus may be indicated on the back by a line from the sixth cervical spinous process to a point 2·5 cm. on the left of the ninth thoracic spinous process.

The **heart.**—The outline of the heart in relation to the front of the thorax (figs. 1238, 1239) can be represented by a quadrangular figure. (*a*) The apex of the heart is first determined as a point in the fifth interspace, 9 cm. to the left of the midsternal line. The other three points are: (*b*) the seventh right sternocostal articulation; (*c*) the upper border of the third right costal cartilage 1 cm. from the right lateral sternal line; (*d*) the lower border of the second left costal cartilage 2·5 cm. from the left lateral sternal line. A line joining (*a*) to (*b*) and

traversing the junction of the body of the sternum with the xiphoid process represents the lower border of the heart. The right and left borders are represented respectively by lines joining (*b*) to (*c*) and (*a*) to (*c*); both lines are convex lateralwards, but the convexity is more marked on the right, where its summit is 4 cm. distant from the midsternal line opposite the fourth costal cartilage.

A portion of the area of the heart thus mapped out is uncovered by lung, and therefore gives a dull note on percussion; the remainder is overlapped by lung and gives a more or less resonant note. The former is known as the area of superficial cardiac dulness, the latter as the area of deep cardiac dulness. The area

Fig. 1239.—A diagram showing the relations of the opened heart to the front of the thoracic wall.



Ant. Anterior segment of tricuspid valve. AO. Aorta. A.P. Anterior papillary muscle. In. Innominate artery. L.C.C. Left common carotid artery. L.S. Left subclavian artery. L.V. Left ventricle. P.A. Pulmonary artery. R.A. Right atrium. R.V. Right ventricle. V.S. Ventricular septum.

of superficial cardiac dulness is somewhat triangular; from the apex of the heart two lines are drawn to the midsternal line, one to the level of the fourth costal cartilage, the other to the junction between the body and xiphoid process of the sternum; the portion of the midsternal line between these points is the base of the triangle. Latham lays down the following rule as a sufficient practical guide for the definition of the area of superficial dulness: 'Make a circle of two inches in diameter round a point midway between the nipple and the end of the sternum.'

The *coronary sulcus* (auriculoventricular groove) can be indicated by a line from the midsternal line opposite the third costal cartilage, to the sixth right sternocostal joint. The *anterior longitudinal sulcus* is a finger's-breadth to the right of the left margin of the heart and parallel with it.

The positions of the orifices of the heart are as follows: the *pulmonary orifice* is situated in the upper angle of the third left sternocostal articulation; the *aortic orifice* is a little below and medial to this, close to the articulation; the *left atrioventricular orifice* is opposite the fourth costal cartilage, and rather to the left of the midsternal line; the *right atrioventricular orifice* is a little lower, opposite

The size of the spleen slowly increases during digestion, and varies according to the state of nutrition of the body, being large in highly fed, and small in starved, animals. In malarial fever it is greatly enlarged, and may weigh as much as 9 kilos.

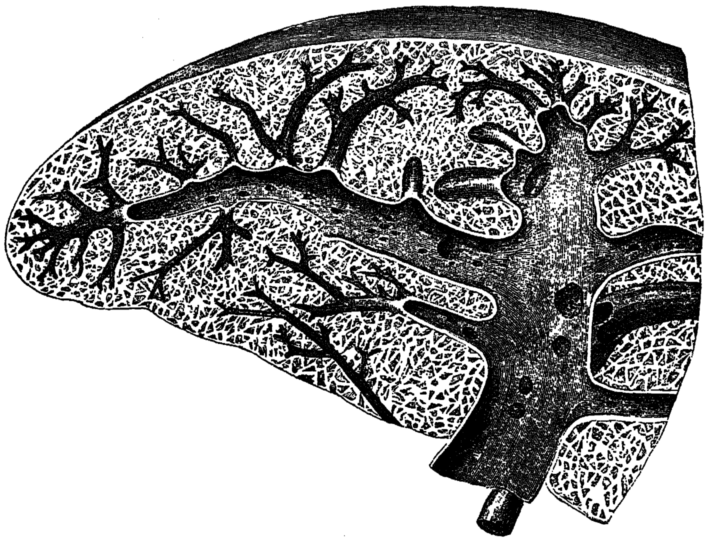
Frequently in the neighbourhood of the spleen, and especially in the gastrolienal ligament and greater omentum, small encapsulated nodules of splenic tissue may be found, either isolated or connected to the spleen by thin bands of splenic tissue. They are known as *accessory spleens.*

Structure.—The spleen is invested by two coats: an external serous and an internal fibro-elastic coat.

The *external or serous coat* is derived from the peritoneum; it is thin, smooth, and in the human subject intimately adherent to the fibro-elastic coat. It invests the entire organ, except at the hilum and along the lines of reflection of the lienorenal and gastrolienal ligaments.

The *fibro-elastic coat* or *tunica propria* invests the organ, and at the hilum is reflected inwards upon the vessels in the form of sheaths. From these sheaths, as well as from the

FIG. 1210.—A transverse section through the spleen, showing the trabecular tissue and the splenic vein and its tributaries.



inner surface of the fibro-elastic coat, numerous small fibrous bands, *trabeculæ* (fig. 1210), are given off in all directions; these unite to form the framework of the spleen, in the interspaces of which is contained the *splenic pulp.*

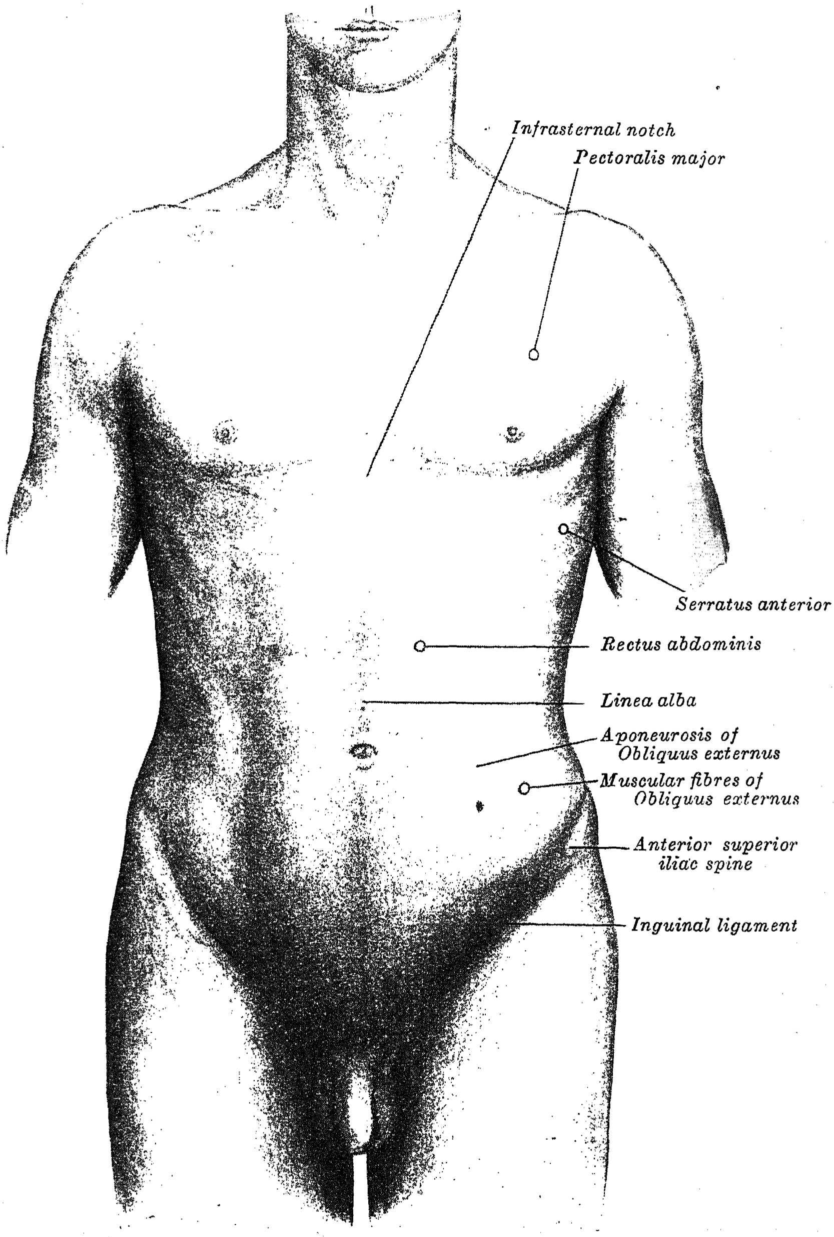
The fibro-elastic coat, the sheaths of the vessels, and the trabeculæ, are composed of white, and yellow elastic, fibres, the latter predominating. It is owing to the presence of the elastic tissue that the spleen possesses a considerable amount of elasticity, which allows of the very great variations in size that it presents under certain circumstances. In addition to these constituents there is a small amount of non-striped muscular fibre. In some mammals (e.g. dog, pig, and cat) the trabeculæ consist chiefly of muscular tissue.

The *splenic pulp* is a soft mass of a dark reddish-brown colour; it consists of a fine reticulum of fibres, continuous with those of the trabeculæ, to which are applied flat, branching cells. The meshes of the reticulum are filled with blood, in which, however, the white corpuscles are found to be in larger proportion than they are in ordinary blood. Large, rounded cells, termed *splenic cells,* are also seen; these are capable of amœboid movement, and often contain pigment and red blood-corpuscles in their interior. The cells of the reticulum each possess a round or oval nucleus, and like the splenic cells they may contain pigment-granules in their cytoplasm; they do not stain deeply with carmine, and in this respect differ from the cells of the Malpighian bodies. In the young spleen giant cells may be found, each containing numerous nuclei or one compound nucleus. Nucleated red blood-corpuscles have also been found in the spleen in young animals.

Blood-vessels of the spleen.—The lienal artery is remarkable for its large calibre in proportion to the size of the organ, and also for its tortuous course. It divides into six or more branches, which enter the hilum of the spleen and ramify throughout its substance (fig. 1211) receiving sheaths from an involution of the external fibrous tissue. Similar sheaths also invest the nerves and veins.

midway between this point and the umbilicus, are usually well marked; the third, opposite the umbilicus, is not so distinct. Between the two Recti the furrow of the linea alba can be traced from the xiphoid process to a point just below the umbilicus, beyond which it disappears owing to the apposition of the muscles;

Fig. 1240.—The surface anatomy of the front of the thorax and abdomen.



above the umbilicus the linea alba is felt as a band, whilst below, it is a rounded cord.

The **vessels.**—In thin subjects the pulsation of the *abdominal aorta* is felt on making deep pressure in the middle line above the umbilicus.

The **viscera.**—Under normal conditions the various portions of the *digestive tube* cannot be identified by simple palpation, but under certain conditions peristalsis

of the coils of small intestine can be observed in persons with extremely thin abdominal walls. In cases of constipation it is commonly possible to trace portions of the great intestine by feeling the fæcal masses within the gut. In thin persons with relaxed abdominal walls the iliac portion of the descending colon can be felt in the left iliac region—rolling under the fingers when empty, and forming a distinct tumour when distended.

The *liver* lies mainly under cover of the lower ribs and their cartilages, but in the epigastric fossa a portion of it comes in contact with the abdominal wall. The position of the liver varies according to the posture of the body. In the erect posture the inferior margin of the liver projects about 1 cm. below the lower margin of the right costal cartilages, and can often be felt if the abdominal wall is thin. In the supine position the liver recedes above the lower margin of the thorax and cannot then be detected by the fingers; in the prone position it falls forwards and is then generally palpable in a patient with lax abdominal walls. Its position varies with the respiratory movements; during a deep inspiration it descends below the ribs, in expiration it is raised. Pressure from without, as in tight lacing, displaces the liver considerably, its anterior edge frequently extending as low as the iliac crest. Again, the position of the liver varies greatly with the state of the stomach and intestines; when these are empty the liver descends, when they are distended it is pushed upwards.

The *pancreas* can sometimes be felt in emaciated subjects, if the stomach and colon are empty, by making deep pressure in the middle line about 7 or 8 cm. above the umbilicus.

The *spleen*, unless it is enlarged or misplaced, cannot be felt.

The *kidneys* are deeply situated at the back of the abdominal cavity; they can be palpated bimanually, i.e. with one hand pressing forwards in the loin between the last rib and the iliac crest, and the other pressing strongly backwards under the costal margin in the lateral abdominal line.

THE SURFACE MARKINGS OF THE ABDOMEN

The **bony landmarks.**—Above, the chief bony markings are the xiphoid process, the lower six costal cartilages and the anterior ends of the lower six ribs. The junction between the body of the sternum and the xiphoid process is at the level of the fibrocartilage between the ninth and tenth thoracic vertebræ. Below, the main landmarks are the symphysis pubis, the pubic crest and tubercle, the anterior superior iliac spine, and the iliac crest.

The **muscles** (fig. 1240).—The Rectus abdominis lies between the linea alba and the linea semilunaris; the latter is indicated by a curved line, convex lateralwards, from the tip of the cartilage of the ninth rib to the pubic tubercle; at the level of the umbilicus the linea semilunaris is about 7 cm. from the middle line, i.e. about midway between the umbilicus and the anterior superior iliac spine. The line indicating the junction of the muscular fibres of Obliquus externus with its aponeurosis extends from the tip of the ninth costal cartilage to a point just medial to the anterior superior iliac spine.

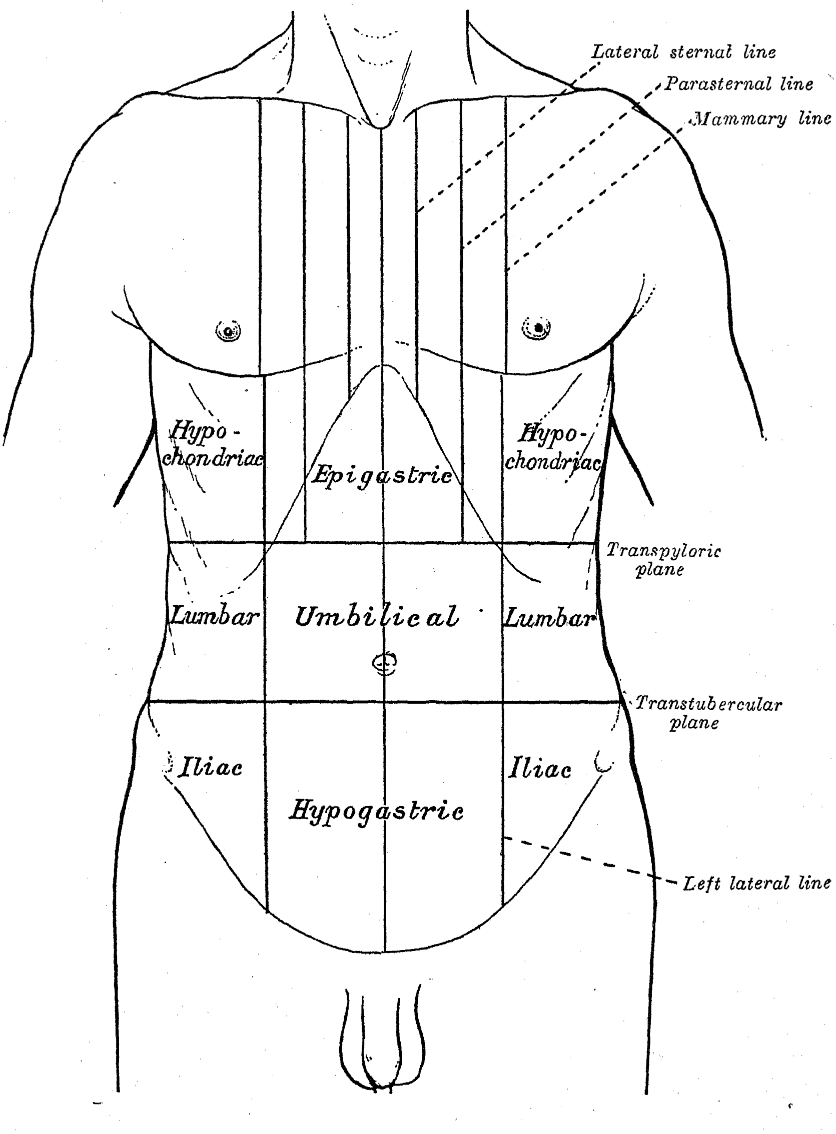
The *umbilicus* is at the level of the middle of the body of the fourth lumbar vertebra.

The centre of the *subcutaneous inguinal ring* is situated 1 cm. above and lateral to the pubic tubercle; the centre of the *abdominal inguinal ring* is about 1 cm. above the middle of the inguinal ligament. The position of the *inguinal canal* is indicated by a line joining these two points.

The **surface lines.**—For convenience of description of the viscera and of reference to morbid conditions of the contained parts, the abdomen is divided into nine regions, by imaginary planes, two horizontal and two sagittal, the edges of the planes being indicated by lines drawn on the surface of the body (fig. 1241). In the older method the upper, or subcostal, horizontal line encircles the body at the level of the lowest points of the tenth costal cartilages; the lower, or intertubercular, is a line carried through the highest points of the iliac crests seen from the front, i.e. through the tubercles on the iliac crests about 5 cm. behind the anterior superior spines. An alternative method is that of Addison, who adopted the following lines: (1) an upper transverse, the *transpyloric*, halfway between the jugular notch

and the upper border of the symphysis pubis; this indicates the edge of the transpyloric plane which in most cases cuts through the pylorus, the tips of the ninth costal cartilages and the lower border of the first lumbar vertebra; clinically it is convenient but not so accurate to draw this line transversely through a point midway between the infrasternal notch and the umbilicus; (2) a lower transverse

FIG. 1241.—The surface lines of the front of the thorax and abdomen.



line midway between the transpyloric and the upper border of the symphysis pubis; this is termed the *transtubercular* since it very nearly corresponds to that passing through the tubercles on the iliac crests; behind, its plane cuts the body of the fifth lumbar vertebra.

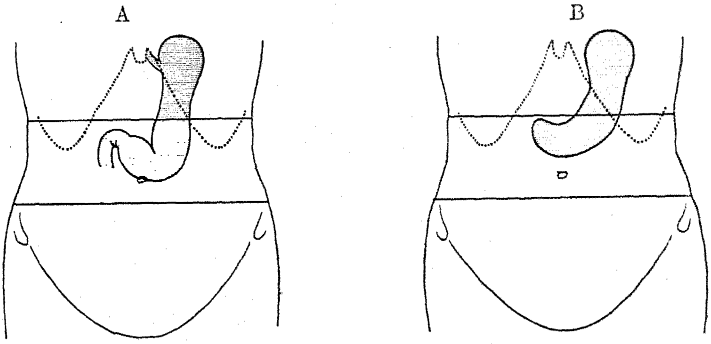
By means of these horizontal planes the abdomen is divided into three zones named from above, subcostal, umbilical, and hypogastric. Each of these is further subdivided into three regions by the two sagittal planes, which are indicated on the surface by a right and a left lateral line drawn vertically through points halfway between the anterior superior iliac spine and the middle line. The middle region of the upper zone is called the epigastric, and the lateral regions the right and

left hypochondriac. The central region of the middle zone is the umbilical, and the lateral regions the right and left lumbar. The middle region of the lower zone is the hypogastric or pubic, and the lateral regions are the right and left iliac or inguinal. The epigastric, umbilical, and pubic regions can each be divided into right and left portions by the middle line. In the following description of the viscera the regions marked out by Addison's lines are those referred to.

The **stomach** (fig. 1243).—The shape of the stomach is constantly undergoing alteration; it is affected by the particular phase of the process of gastric digestion, by the state of the surrounding viscera, and by the amount and character of its contents. Its position also varies with that of the body (fig. 1242), so that it is impossible to indicate it on the surface with any degree of accuracy. The measurements given refer to a moderately filled stomach with the body in the supine position.

The cardiac orifice is opposite the seventh left costal cartilage about 2·5 cm. from the side of the sternum; it corresponds to the level of the tenth thoracic vertebra. The pyloric orifice is on the transpyloric line about 1 cm. to the right of the middle line, or alternatively 5 cm. below the seventh right sternocostal

FIG. 1242.—Skiagrams of a half-filled stomach, showing the influence of posture. (After A. F. Hurst.)



A. With the patient in the erect posture. B. With the patient lying down.

articulation; it is at the level of the first lumbar vertebra. A curved line, convex downwards and to the left, joining these points indicates the lesser curvature. In the left lateral line the fundus of the stomach reaches as high as the fifth intercostal space or the sixth costal cartilage, a little below the apex of the heart. To indicate the greater curvature a curved line is drawn from the cardiac orifice to the summit of the fundus, thence downwards and to the left, finally turning medialwards to the pyloric orifice, but passing on its way, through the intersection of the left lateral with the transpyloric line. The portion of the stomach which is in contact with the abdominal wall can be represented roughly by a triangular area, the base of which is formed by a line drawn from the tip of the tenth left costal cartilage to the tip of the ninth right cartilage, and the sides by two lines drawn from the end of the eighth left costal cartilage to the ends of the base line.

A space of some clinical importance—the *space of Traube*—overlies the stomach; it is semilunar in outline and has the following boundaries: the lower edge of the left lung, the anterior border of the spleen, the left costal margin, and the inferior margin of the left lobe of the liver.

The **duodenum** (fig. 1244).—The superior part is nearly horizontal and extends from the pylorus to the right lateral line; the descending part is situated medial to the right lateral line, and reaches from the transpyloric line to a point midway between the transpyloric and transtubercular lines. The horizontal part runs with a slight upward slope from the end of the descending part to the left of the middle line; the ascending part is vertical, and ends in the duodenojejunal flexure, about 2·5 cm. to the left of the middle line and a little below the transpyloric plane.

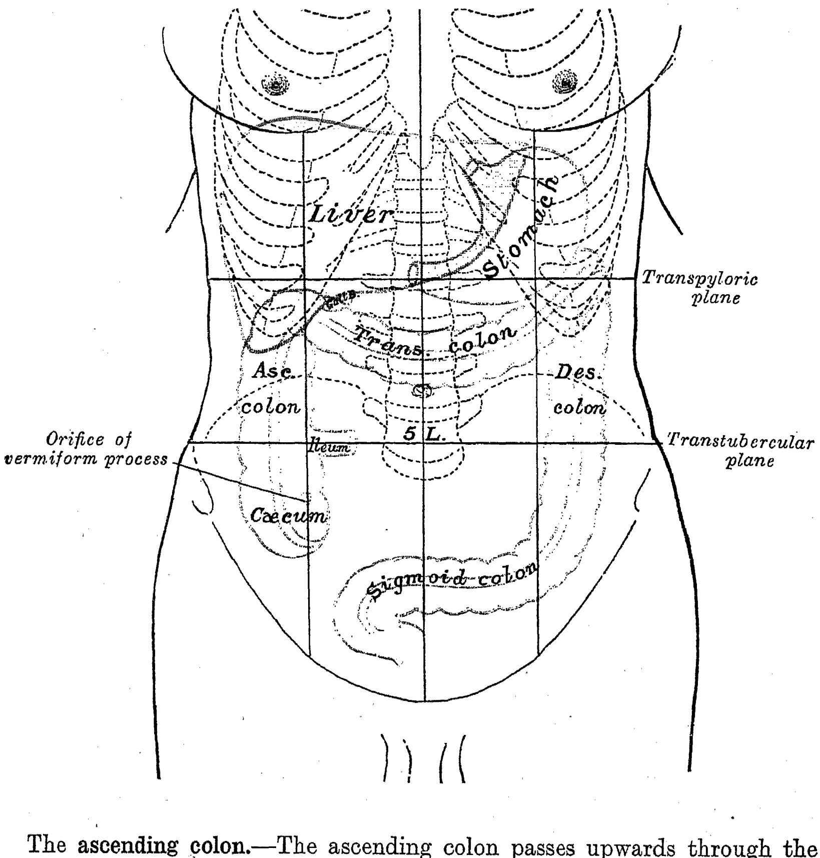
The **small intestine**.—The coils of small intestine occupy the front of the abdomen. For the most part those of the jejunum are situated on the left side, i.e. in the left lumbar and iliac regions, and in the left half of the umbilical region. Those

of the ileum lie towards the right in the right lumbar and iliac regions, in the right half of the umbilical region, and in the hypogastric region; a portion of the ileum is within the pelvis. The end of the ileum, i.e. the *ileocolic junction*, is slightly below and medial to the intersection of the right lateral and transtubercular lines.

The **cæcum** and **vermiform process.**—The *cæcum* is in the right iliac and hypogastric regions; its position varies with its degree of distension, but the midpoint of a line drawn from the right anterior superior iliac spine to the upper margin of the symphysis pubis will mark approximately the middle of its lower border.

The position of the opening of the *vermiform process* into the cæcum is indicated by a point on the right lateral line on a level with the anterior superior iliac spine.

FIG. 1243.—The front of the abdomen, showing the surface markings for the liver, stomach, and large intestine.



The **ascending colon.**—The ascending colon passes upwards through the right lumbar region, just lateral to the right lateral line. The *right colic flexure* is situated in the right lower angle of intersection of the transpyloric and right lateral lines.

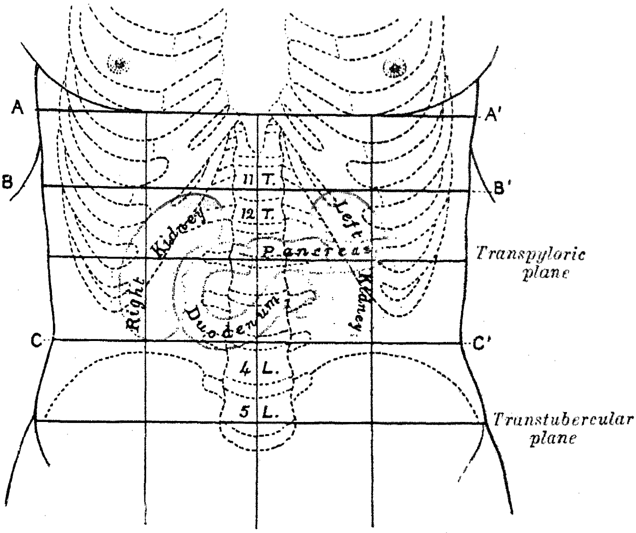
The **transverse colon.**—The transverse colon crosses the abdomen; its lower border is slightly above the level of the umbilicus, its upper border just below the greater curvature of the stomach.

The **descending colon.**—The *left colic flexure* is situated in the upper left angle of the intersection between the left lateral and transpyloric lines. The descending colon courses down through the left lumbar region, lateral to the left lateral line, thence slightly medialwards to cross the left lateral line at the level of the anterior superior iliac spine.

The **liver** (fig. 1243).—The upper limit of the right lobe of the liver, in the middle line, is at the level of the junction between the body and xiphoid process of the sternum; on the right side the line must be carried upwards as far as the fifth costal cartilage in the mammary line, and then downwards to reach the seventh rib at the side of the thorax. The upper limit of the left lobe can be defined by continuing

this line to the sixth left costal cartilage, 5 cm. from the middle line. The lower limit is represented by a line drawn 1 cm. below the lower margin of the thorax

FIG. 1244.—The front of the abdomen, showing the surface markings for the duodenum, pancreas and kidneys.



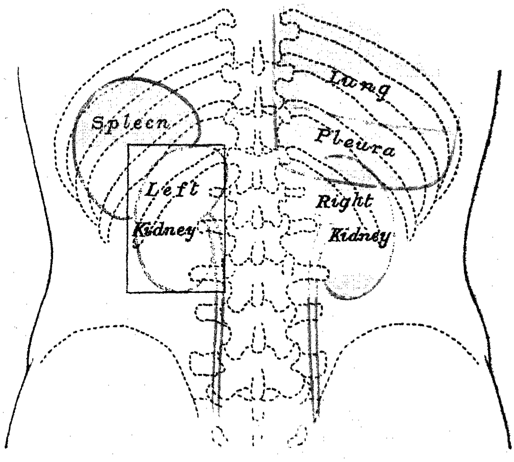
A A'. Plane through the joint between the body and xiphoid process of sternum. B B'. Plane midway between A A' and transpyloric plane. C C'. Plane midway between transpyloric and transtubercular planes.

on the right side as far as the ninth costal cartilage, thence obliquely upwards to the eighth left costal cartilage, crossing the middle line at the transpyloric plane and finally, with a slight left convexity, to the end of the line indicating the upper limit.

According to Birmingham, the limits of the normal liver may be marked out on the surface of the body in the following manner. Take three points: (*a*) 1·25 cm. below the right nipple; (*b*) 1·25 cm. below the tip of the right tenth rib; (*c*) 2·5 cm. below the left nipple. Join (*a*) and (*c*) by a line slightly concave upwards at its middle part; (*a*) and (*b*) by a line slightly convex lateralwards; and (*b*) and (*c*) by a line slightly convex downwards.

The fundus of the *gall-bladder* approaches the surface behind the anterior end of the ninth right costal cartilage close to the lateral margin of the Rectus abdominis.

FIG. 1245.—The back of the lumbar region, showing the surface markings for the kidneys, ureters, and spleen.



The lower portions of the lung and pleura are shown on the right side.

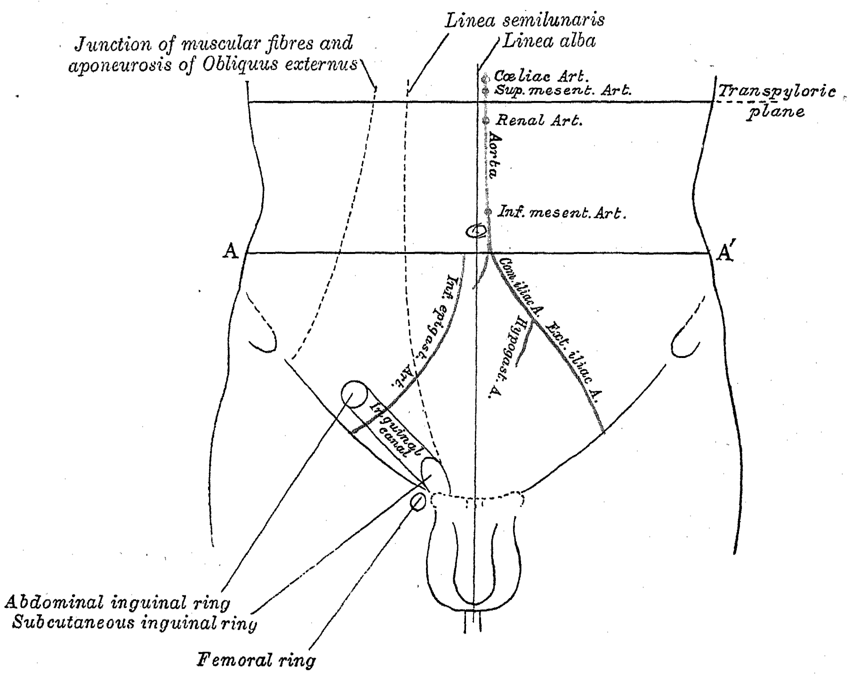
The **pancreas** (fig. 1244).—The pancreas lies in front of the first and second lumbar vertebræ. Its head occupies the curve of the duodenum, and is therefore indicated by the same lines as that viscus; its neck corresponds to the pylorus. Its body extends along the transpyloric line, the bulk of it lying above this line, to the tail, which is in the

left hypochondriac region slightly to the left of the lateral line and above the transpyloric line.

The **spleen** (figs. 1238, 1245).—To map out the spleen the tenth rib is taken as representing its long axis; vertically it extends from the upper border of the ninth rib to the lower border of the eleventh rib. The highest point is 4 cm. from the middle line of the back at the level of the tip of the ninth thoracic spinous process; the lowest and foremost point is in the midaxillary line at the level of the first lumbar spinous process.

The **kidneys** (figs. 1244, 1245).—The right kidney usually lies about 1 cm. lower than the left, but for practical purposes similar surface markings are taken for each.

FIG. 1246.—The front of the abdomen, showing the surface markings for the arteries and the inguinal canal. The line A, A is drawn at the level of the highest points of the iliac crests.



On the front of the abdomen the upper pole lies midway between the plane of the lower end of the body of the sternum and the transpyloric plane, 5 cm. from the middle line. The lower pole is situated midway between the transpyloric and transtubercular planes, 7 cm. from the middle line. The hilum is on the transpyloric plane, 5 cm. from the middle line.* Round these three points a kidney-shaped figure 4 cm. to 5 cm. broad is drawn two-thirds of which lie medial to the lateral line. To indicate the position of the kidney from the back, the parallelogram of Morris is used; two vertical lines are drawn, the first 2·5 cm., the second 9·5 cm. from the middle line; the parallelogram is completed by two horizontal lines, one drawn at the level of the tip of the spinous process of the eleventh thoracic vertebra, and the other at the level of the lower border of the spinous process of the third lumbar vertebra. The hilum is 5 cm. from the middle line at the level of the spinous process of the first lumbar vertebra.

The **ureters**.—On the front of the abdomen, the line of the ureter is from the hilum of the kidney to the pubic tubercle; on the back, from the hilum vertically downwards, passing through the posterior superior iliac spine (fig. 1245).

The **arteries** (fig. 1246).—The position of the *inferior epigastric artery* is marked by a line from a point midway between the anterior superior iliac spine and the

* Addison says that (1) one-third of the right kidney and two-fifths of the left are above the transpyloric plane, and (2) one-third of the right kidney and two-fifths of the left lie on the medial side of the corresponding lateral line.

pubic symphysis to the umbilicus. This line also indicates the lateral boundary of *Hesselbach's triangle*, the other boundaries of which are the lateral edge of Rectus abdominis, and the medial half of the inguinal ligament. The line of the *abdominal aorta* begins in the middle line about 4 cm. above the transpyloric line and ends at a point 2 cm. below and to the left of the umbilicus—or 2 cm. to the left of the middle line at the level of the highest points of the iliac crests (AA', fig. 1246); the abdominal aorta ends at the level of the fourth lumbar vertebra. A line drawn from the point of termination of the abdominal aorta to a point midway between the anterior superior iliac spine and the symphysis pubis overlies the common and external iliac arteries. The *common iliac artery* is represented by the upper one-third, and the *external iliac artery* by the lower two-thirds of this line.

Of the larger branches of the abdominal aorta, the *cœliac artery* is 4 cm., and the *superior mesenteric artery* 2 cm. above the transpyloric line; the *renal arteries* are 2 cm. below this line. The *inferior mesenteric artery* is 4 cm. above the bifurcation of the abdominal aorta.

The **nerves.**—The positions of the lower six thoracic nerves on the anterior abdominal wall are represented by lines continuing those of the ribs. The seventh thoracic nerve ends at the level of the xiphoid process, the tenth at the level of the umbilicus, and the twelfth about midway between the umbilicus and the upper border of the symphysis pubis. The anterior branch of the iliohypogastric nerve becomes cutaneous about 3 cm. above the subcutaneous inguinal ring; the ilio-inguinal nerve at the ring.

THE SURFACE ANATOMY OF THE PERINÆUM

The **skin.**—In the middle line of the posterior part of the perinæum and about 4 cm. in front of the tip of the coccyx is the anal orifice, the skin around which is thrown into a series of folds which converge towards the orifice, and are continued upwards into the lower part of the anal canal. The junction of the mucous membrane of the anal canal with the skin is marked by a white line which indicates also the line of contact of the external and internal Sphincters. The external genital organs are situated in the anterior part of the perinæum. The skin covering the scrotum is rough and corrugated, but over the penis it is smooth. Extending forwards from the anus on to the scrotum and penis is a median ridge which indicates the scrotal raphe. In the *female* are seen the skin reduplications forming the labia majora and minora laterally, the prepuce of the clitoris in front, and still more anteriorly the mons pubis (fig. 1248).

The **bones.**—In the anterolateral boundaries of the perinæum, the whole outline of the pubic arch can be readily traced ending in the ischial tuberosities. Behind in the middle line is the tip of the coccyx.

The **muscles** and **ligaments.**—The margin of the *Glutæus maximus* forms the posterolateral boundary of the perinæum, and by pressing deeply the sacrotuberous ligament can be felt through the muscle. The only other muscles influencing surface form are the *Ischiocavernosus* covering the crus penis, which lies on the side of the pubic arch, and the *Sphincter ani externus*, which, in action, closes the anal orifice and causes a puckering of the skin around it.

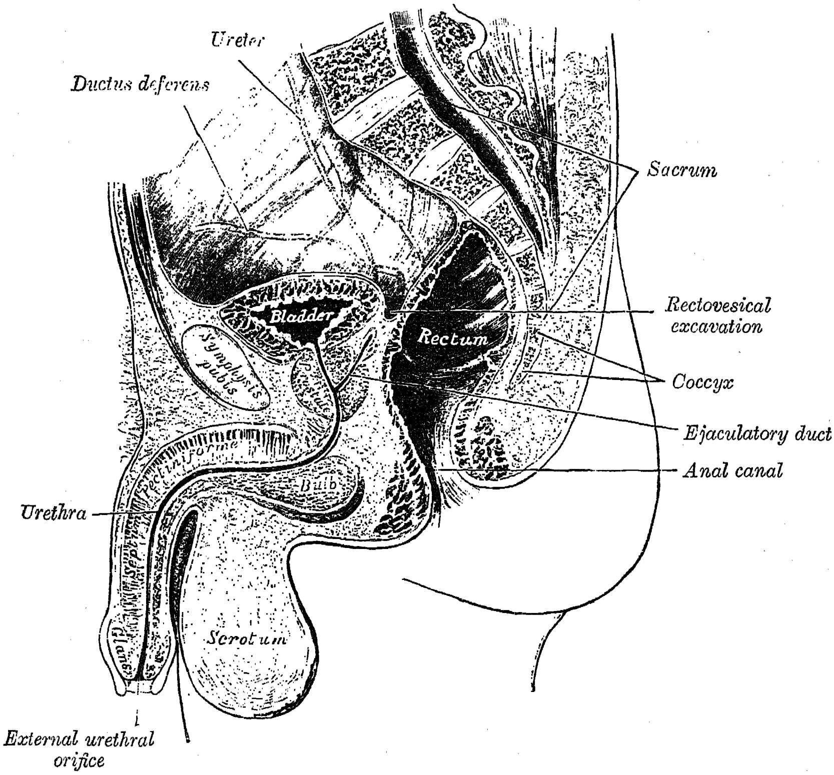
THE SURFACE MARKINGS OF THE PERINÆUM

A line drawn transversely in front of the ischial tuberosities divides the perinæum into a posterior or rectal, and an anterior or urogenital, triangle. This line passes through the central point of the perinæum, which is situated about 2·5 cm. in front of the anal aperture, or, in the male, midway between the anus and the reflection of the skin on to the scrotum.

The **rectum** and **anal canal.**—A finger inserted through the anal orifice enters the anal canal, which passes upwards and forwards for about 2·5 cm. and then bends backwards almost at right angles into the rectum. The finger is first grasped

by the Sphincter ani externus, passes into the region of the Sphincter ani internus, and higher up encounters the resistance of the Puborectalis; beyond this it may reach the lowest of the transverse rectal folds. In front (fig. 1247), the urethral bulb and membranous part of the urethra are first identified, and then about 4 cm. above the anal orifice the prostate is felt: beyond this the vesiculæ seminales, if enlarged, and the fundus of the bladder, when distended, can be recognised. On either side is the ischiorectal fossa. Behind are the anococcygeal body, the pelvic surfaces of the coccyx and lower part of the sacrum, and the sacrospinous ligaments.

FIG. 1247.—A median sagittal section through the male pelvis.



In the female the posterior wall and fornix of the vagina, and the cervix and body of the uterus can be felt in front, while somewhat laterally the ovaries can just be reached.

Further examination of the interior of the lower end of the digestive tube can be accomplished by viewing it through the proctoscope or sigmoidoscope.

The **male urogenital organs.**—The corpora cavernosa penis can be followed backwards to the crura which are attached to the sides of the pubic arch. The glans penis, covered by the prepuce, and the external urethral orifice can be examined, and the course of the urethra traced along the under surface of the penis to the urethral bulb which is situated immediately in front of the central point of the perinæum. The testes can be palpated through the wall of the scrotum, and along the posterior border of each the curved epididymis can be felt; the spermatic cord ascends on the medial side of the epididymis, and may be traced upwards to the subcutaneous inguinal ring. The ductus deferens feels like a piece of whipcord, and thus can be easily recognised in the posterior part of the spermatic cord.

By means of a sound the general topography of the urethra and bladder can be investigated; with the urethroscope the interior of the urethra can be illuminated and viewed directly; with the cystoscope the interior of the bladder may be illuminated in a similar manner for visual examination. In the bladder the main points to

which attention is directed are: the trigone, the torus uretericus, the plicæ uretericæ, and the openings of the ureters and urethra (see fig. 1169).

The **female urogenital organs.**—In the pudendal cleft (fig. 1248) between the labia minora are the openings of the vagina and urethra. In the virgin the vaginal opening is partly closed by the hymen—after coitus the remains of the hymen are represented by the carunculæ hymenales. Between the vaginal orifice and the frenulum of the labia is the fossa navicularis, while in the groove between the hymen and the labium minus, on either side, the small opening of the greater vestibular (Bartholin's) gland is visible. These glands when enlarged can be felt on either side of the posterior part of the vaginal orifice. By inserting a finger into the vagina the following structures may be examined through its wall (fig. 1249).

Fig. 1248.—The external genital organs of the female. The labia minora have been drawn apart.

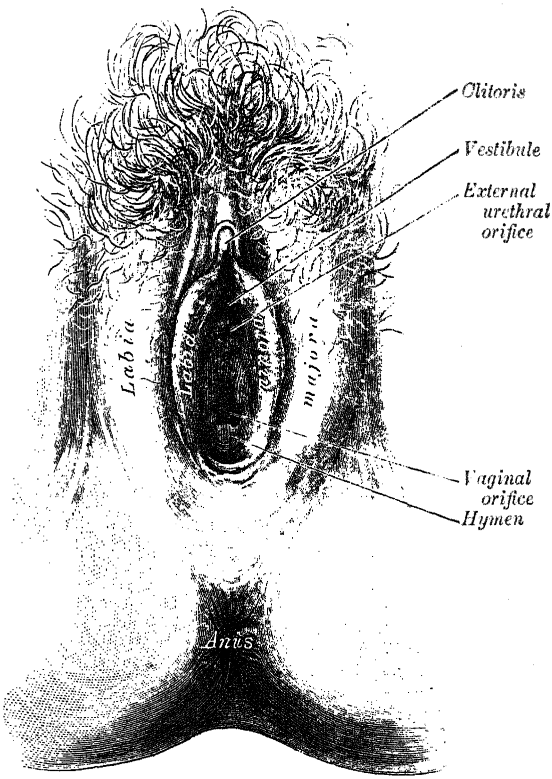
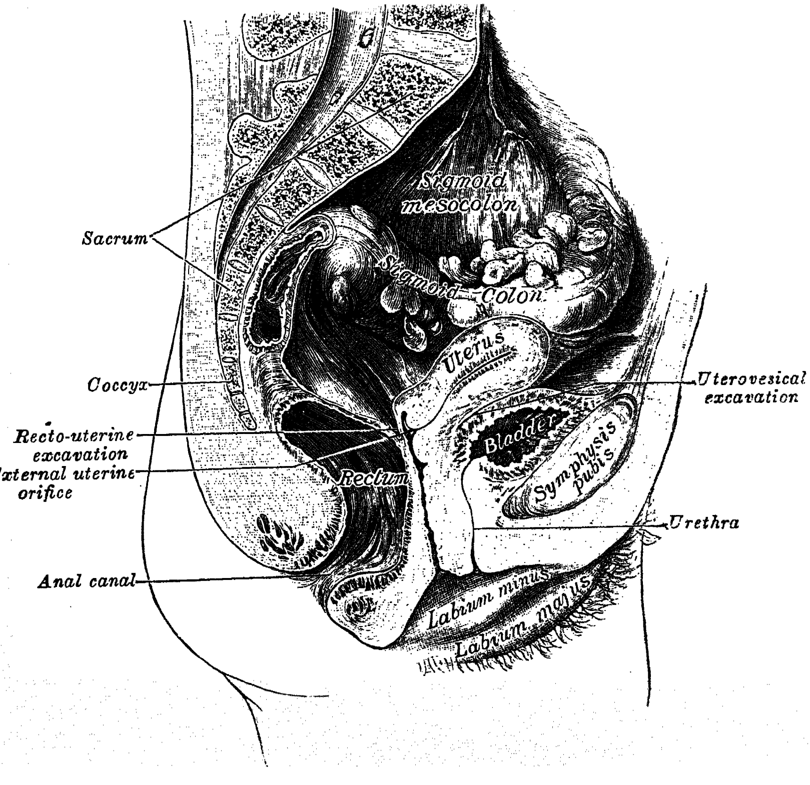


Fig. 1249.—A median sagittal section through the female pelvis.



Behind, from below upwards, are the anal canal, the rectum, and the recto-uterine excavation. Projecting into the roof of the vagina is the vaginal portion of the cervix uteri with the external uterine orifice; in front of and behind the cervix are the anterior and posterior vaginal fornices. With a finger in the vagina and the other hand on the abdominal wall the whole of the cervix and body of the uterus, the uterine tubes, and the ovaries can be palpated; the ureter, as it crosses the lateral fornix to enter the bladder, can be rolled between the finger and the inner surface of the os pubis. If a speculum be introduced into the vagina, the walls of the passage, the vaginal portion of the cervix uteri, and the external uterine orifice can all be exposed for visual examination.

The external urethral orifice lies in front of the vaginal opening, and has rather prominent margins. The urethral canal in the female is very dilatable and can be explored with the finger. About 2·5 cm. in front of the external orifice of the urethra are the glans and prepuce of the clitoris, and still further forward, the mons pubis.

THE SURFACE ANATOMY OF THE UPPER EXTREMITY

The **skin.**—The skin covering the shoulder and arm is smooth and very movable on the underlying structures. In the axilla there are numerous hairs and many sudoriferous and sebaceous glands. On the medial side and front of the forearm the skin is thin and smooth, and contains few hairs but many sudoriferous glands; on the lateral side and back of the arm and forearm it is thicker, denser, and contains more hairs but fewer sudoriferous glands. In the region of the olecranon it is thick and rough; it is very loosely connected to the underlying tissue, and falls into transverse wrinkles when the forearm is extended. At the front of the wrist there are three transverse furrows in the skin; they correspond from above downwards to the positions of the styloid process of the ulna, the radiocarpal or wrist-joint, and the midcarpal joint.

The skin of the palm of the hand is hard and dense, and covered with a thick layer of epidermis; on the thenar eminence these characteristics are less marked than elsewhere. It is exceedingly sensitive and very vascular, but is destitute of hairs and sebaceous glands. It is tied down by fibrous bands along the lines of flexion of the digits, and exhibits certain furrows of a permanent character. One of these furrows begins in front of the wrist at the tuberosity of the navicular bone, curves round the thenar eminence, and ends on the lateral border of the hand near the level of the metacarpophalangeal joint of the index finger; a second begins at the distal end of the first and extends obliquely across the palm to reach the medial border about the middle of the fifth metacarpal bone; a third begins at the medial border about 2·5 cm. distal to the end of the second, and extends across the heads of the fifth, fourth, and third metacarpal bones. The medial part of the third line and the lateral part of the second line lie in front of the metacarpophalangeal joints of the fingers. The proximal segments of the fingers are joined to one another on the volar aspect by folds of skin constituting the 'web' of the fingers; these folds are about opposite the level of the centres of the proximal phalanges and their free margins are continuous with the transverse furrows at the roots of the fingers. Since the web is confined to the volar aspect, the fingers appear shorter when viewed from in front than from behind. Over the fingers and thumb the skin is thinner, especially at the flexures of the joints (where it is crossed by transverse furrows) and over the terminal phalanges; it is disposed in numerous ridges in consequence of the arrangement of the papillæ in it. These ridges form, in different individuals, distinctive and permanent patterns which can be used for purposes of identification.

The superficial fascia in the palm of the hand is made up of dense fibro-fatty tissue which binds the skin so firmly to the palmar aponeurosis that very little movement is permitted between the two.

On the back of the hand and fingers the subcutaneous tissue is lax, and the skin is freely movable on the underlying parts. Over the interphalangeal joints it is very loose and is thrown into transverse wrinkles when the fingers are extended.

The **bones.**—The *clavicle* can be felt throughout its entire length. The enlarged sternal end projects above the sternum at the side of the jugular notch, and from

this the body of the bone can be traced lateralwards under the skin. The medial part is convex forwards, but the surface is partially obscured by the attachments of the Sternocleidomastoideus and Pectoralis major; the lateral one-third is concave forwards and ends in a slight enlargement at the acromion of the scapula. The clavicle is almost horizontal when the arm is lying by the side, although in muscular subjects it may incline a little upwards at its acromial end, which is on a plane posterior to the sternal end.

The only parts of the *scapula* that are subcutaneous are the spine and acromion, but the coracoid process, the vertebral border, the inferior angle, and to a lesser extent the axillary border can be readily defined. The acromion and the posterior border of the spine are easily recognisable throughout their entire extent, forming with the clavicle the arch of the shoulder. The acromion forms the point of the shoulder; it joins the clavicle at an acute angle—the acromial angle—slightly medial to, and behind the tip of the acromion. The spine can be felt in the floor of an oblique depression and becomes less distinct when traced medialwards; it ends in a slight dimple a little lateral to the spinous process of the third thoracic vertebra. Below this point the vertebral border may be followed downwards and lateralwards to the inferior angle, which is easily identified although covered by the Latissimus dorsi. From the inferior angle the axillary border may be traced upwards through its thick muscular covering, forming with its enveloping muscles the posterior fold of the axilla; this fold is more vertical in direction than the anterior fold of the axilla, and can be seen from the front. The coracoid process is situated about 2 cm. below the junction of the intermediate with the lateral one-third of the clavicle; it is covered by the anterior border of the Deltoideus, and thus lies a little lateral to the infraclavicular fossa or depression which marks the interval between the Pectoralis major and Deltoideus.

The *humerus* is almost entirely surrounded by muscles, and the only parts which are subcutaneous are its medial and lateral epicondyles; in addition to these, however, the tubercles and a part of the head of the bone can be felt under the skin and muscles by which they are covered. The greater tubercle forms the most prominent bony point of the shoulder, extending beyond the acromion; it is best recognised when the arm is lying passive by the side, for if the arm be raised it recedes under the arch of the shoulder. The lesser tubercle, directed forwards, is medial to the greater, and is separated from it by the intertubercular sulcus, which can be made out by deep pressure. When the arm is abducted the lower part of the head of the humerus can be felt by pressing deeply in the axilla. On either side of the elbow-joint and just above it are the medial and lateral epicondyles. Of these, the former is the more prominent, but the medial supracondylar ridge is much less marked than the lateral, and as a rule is not palpable; occasionally, however, the hook-shaped supracondylar process (p. 284*) is found on this border. The position of the lateral epicondyle is best seen during semiflexion of the forearm, and is indicated by a depression; from it the strongly marked lateral supracondylar ridge runs upwards.

The most prominent part of the *ulna*, the olecranon, can always be identified at the back of the elbow-joint; when the forearm is flexed its upper quadrilateral surface is palpable, but during extension this surface recedes into the olecranon fossa. During extension the upper border of the olecranon is slightly above the level of the medial epicondyle and nearer to this than to the lateral epicondyle; when the forearm is fully flexed the olecranon and the epicondyles form the angles of an equilateral triangle. On the back of the olecranon is a smooth triangular subcutaneous surface, and running down the back of the forearm from the apex of this triangle the sinuous dorsal border of the ulna can be felt in its whole length: above, it is situated in the middle of the back of the limb; but below, where it is rounded off, it may be traced to the small subcutaneous surface of the styloid process on the medial side of the wrist. The styloid process forms a prominent tubercle continuous above with the dorsal border and ending below in a blunt apex at the level of the wrist-joint; it is most evident when the hand is in a position midway between supination and pronation. When the forearm is pronated the head of the ulna projects on the back of the wrist; between the head and styloid process of the ulna is the groove which lodges the tendon of the Extensor carpi ulnaris.

Below the lateral epicondyle of the humerus a portion of the head of the *radius* is palpable; its position is indicated on the surface by a little dimple which is best seen when the arm is extended. If a finger be placed in this dimple and the

semiflexed forearm pronated and supinated the head of the radius will be felt rotating in the radial notch. The upper half of the body of the bone is obscured by muscles; the lower half can be readily examined, and when traced downwards is found to end in a lozenge-shaped convex surface on the lateral side of the base of the styloid process; this is the only subcutaneous part of the bone, and from its lower end the apex of the styloid process bends medialwards towards the wrist. The styloid process of the radius is about 1·25 cm. below the level of the styloid process of the ulna. About the middle of the dorsal surface of the lower end of the radius is the dorsal radial tubercle, best perceived when the wrist is slightly flexed; it forms the lateral boundary of the oblique groove in which the tendon of the Extensor pollicis longus lies.

On the front of the wrist are two subcutaneous eminences, one, on the radial side, produced by the tuberosity of the *navicular bone*, and the ridge on the *greater multangular bone*; the other, on the ulnar side, by the *pisiform bone*. These eminences are crossed by the most distal of the three transverse skin furrows on the front of the wrist. The rest of the volar surface of the carpus is covered by tendons and the transverse carpal ligament, and is entirely concealed, with the exception of the hamulus of the *hamate bone*, which, however, is difficult to define. On the dorsal surface of the carpus the *triquetral bone* can be clearly made out, and when the wrist-joint is acutely flexed the head of the capitate bone may be felt.

The dorsal surfaces of the *metacarpal bones*, except that of the fifth, are covered by the extensor tendons, and are visible only in very thin hands; the dorsal surface of the fifth is, however, subcutaneous throughout almost its whole length. The styloid process of the third metacarpal bone is frequently well marked; it forms a prominence situated slightly lateral to the middle line of the hand and about 4 cm. distal to the dorsal radial tubercle. The heads of the metacarpal bones are rounded in contour and stand out in bold relief under the skin when the fist is clenched; the head of the third is the most prominent. In the palm of the hand the metacarpal bones of the fingers are covered by muscles, tendons, and aponeuroses, so that only their heads can be distinguished. The base of the metacarpal bone of the thumb, however, is prominent dorsally, and the body of the bone is easily palpable, ending at the head in a flattened prominence in front of which are the sesamoid bones.

The enlarged ends of the *phalanges* can be easily felt. When the digits are flexed, a slight concavity can be recognised on the distal end of each of the first phalanges; the distal ends of the second phalanges are flattened and square-shaped.

The **articulations.**—The *sternoclavicular joint* is subcutaneous, and its position is indicated by the enlarged sternal extremity of the clavicle, lateral to the long cord-like sternal head of Sternocleidomastoideus. If this muscle be relaxed a depression between the end of the clavicle and the sternum can be felt, defining the exact position of the joint.

The position of the *acromioclavicular joint* is ascertained by determining the slightly enlarged acromial end of the clavicle which projects above the level of the acromion; sometimes this enlargement is so considerable as to form a rounded eminence. The *shoulder-joint* is deeply seated and cannot be palpated.

When the forearm is slightly flexed a curved crease or fold with its convexity downwards is seen in front of the elbow, extending from one epicondyle to the other; the *elbow-joint* is slightly distal to the middle of the fold. The position of the radiohumeral part of the joint can be ascertained by feeling for a slight groove or depression between the head of the radius and the capitulum of the humerus, at the back of the elbow-joint.

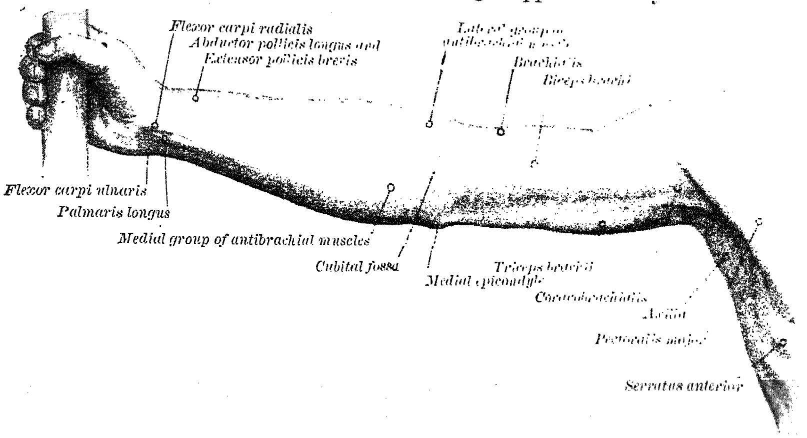
The position of the *proximal radio-ulnar joint* is marked on the surface at the back of the elbow by the dimple which indicates the position of the head of the radius. The site of the *distal radio-ulnar joint* can be defined by feeling for the slight groove at the back of the wrist, between the prominent head of the ulna and the lower end of the radius, when the forearm is in a state of almost complete pronation.

Of the three transverse skin furrows on the front of the wrist, the middle corresponds fairly accurately with the *radiocarpal or wrist-joint*, and the most distal indicates the position of the *midcarpal articulation*.

The *metacarpophalangeal* and *interphalangeal joints* are readily available for surface examination; the former are situated just distal to the prominences of the knuckles, the latter are sufficiently indicated by the furrows on the volar, and the wrinkles on the dorsal, surfaces.

The **muscles** (figs. 1250, 1251).—The anterior border of the *Trapezius* presents as a slight ridge running downwards and forwards from the superior nuchal line of the occipital bone to the junction of the intermediate with the lateral one-third of the clavicle. The inferior border of the muscle forms an undulating ridge passing downwards and medialwards from the root of the spine of the scapula to the spinous process of the twelfth thoracic vertebra.

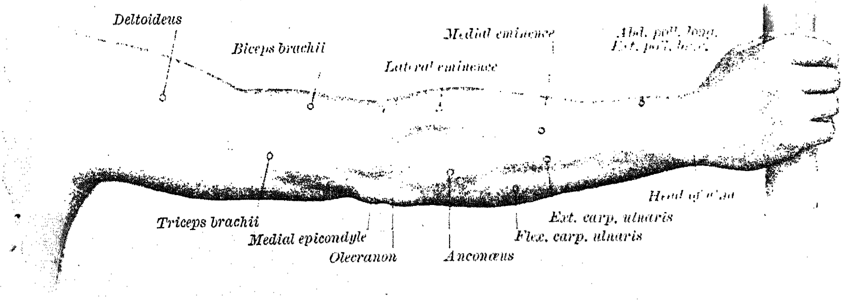
Fig. 1250.—The front of the right upper extremity.



The lateral border of the *Latissimus dorsi* (fig. 1236) may be traced, when the muscle is in action, as a rounded edge starting from the iliac crest a little lateral to the Sacrospinalis, and slanting obliquely forwards and upwards to the axilla, where it takes part with the Teres major in forming the posterior axillary fold; the Latissimus dorsi forms the medial rounded muscular part of the fold, the Teres major the thinner lateral part.

The *Pectoralis major* (fig. 1240) conceals a considerable part of the thoracic wall in front. Its sternal origin presents a border which bounds and determines the width of the sternal furrow. The upper margin is generally well marked near the clavicle, and forms the medial boundary of the infraclavicular fossa, which separates the Pectoralis major from the Deltoideus; it gradually becomes less distinct as it approaches the tendon of insertion and cannot be differentiated from the Deltoideus. The lower border of the Pectoralis major forms the rounded

Fig. 1251.—The back of the right upper extremity.



anterior axillary fold. Occasionally a gap is visible between the clavicular and sternal parts of the muscle.

When the arm is raised the lowest slip of origin of the *Pectoralis minor* produces a fulness below the anterior axillary fold and serves to break the sharp outline of the lower border of the Pectoralis major.

The origin of the *Serratus anterior* (figs. 1236, 1240) causes a very characteristic surface marking. When the arm is abducted the lower five or six serrations can

be seen, separated from those of the Obliquus externus abdominis by a zigzag line. When the arm is by the side the highest visible serration is that attached to the fifth rib.

The *Deltoideus* with the underlying prominence of the upper end of the humerus produces the rounded contour of the shoulder; it is rounder and fuller in front than behind, where it presents a somewhat flattened form. Above, its anterior border presents a slightly curved eminence which forms the lateral boundary of the infraclavicular fossa; below, it is closely united with the Pectoralis major. Its posterior border is thin, flattened, and scarcely evident above, but is thicker and more prominent below. The insertion of the Deltoideus is marked by a depression on the lateral side of the middle of the arm.

Of the scapular muscles the *Teres major* assists the Latissimus dorsi to form the thick, rounded posterior axillary fold.

When the arm is raised the *Coracobrachialis* appears as a narrow elevation emerging from under cover of the anterior axillary fold and running medially to the upper half of the body of the humerus.

On the front and medial aspects of the arm is the prominence of the *Biceps brachii,* bounded on either side by a depression. It determines the contour of the front of the arm and extends from the anterior axillary fold to the bend of the elbow; its upper tendons are concealed by the Pectoralis major and Deltoideus, and its lower tendon sinks into the cubital fossa. When the muscle is fully contracted it presents a globular form, and the lacertus fibrosus (bicipital fascia) attached to its tendon of insertion becomes prominent as a sharp ridge running downwards and medialwards.

On either side of the Biceps brachii at the lower part of the arm the *Brachialis* is discernible. Laterally it forms a narrow eminence extending some distance up the arm; medially it produces only a slight fulness above the elbow.

On the back of the arm the long head of the *Triceps brachii* may be seen as a longitudinal eminence, emerging from under cover of the Deltoideus and gradually passing into the flattened plane of the tendon of insertion of the muscle at the lower part of the back of the arm. When the muscle is in action its medial and lateral heads are prominent.

On the front of the elbow are two muscular elevations, one on either side, which converge below and form the medial and lateral boundaries of the cubital fossa. The medial elevation consists of the Pronator teres and the flexors, and is fusiform, pointed above at the medial epicondyle, and gradually tapering off below. The *Pronator teres* is the most lateral of the group, while the *Flexor carpi radialis,* lying to its medial side, is the most prominent and may be traced downwards to its tendon; this tendon is easily identified as far as the front of the wrist where it is placed on the medial side of the radial artery and on the lateral side of the median nerve. The *Palmaris longus* presents no surface marking above, but below, its tendon stands out when the muscle is in action as a sharp cord in front of the middle of the wrist, just medial to the tendon of the Flexor carpi radialis, and immediately in front of the median nerve. The *Flexor digitorum sublimis* does not directly influence surface form; the position of its four tendons on the front of the lower part of the forearm is indicated by an elongated depression between the tendon of the Palmaris longus and that of the Flexor carpi ulnaris. The *Flexor carpi ulnaris* determines the contour of the medial border of the forearm, and is separated from the extensor group of muscles by the ulnar furrow the floor of which is formed by the subcutaneous dorsal border of the ulna; its tendon is evident along the ulnar border of the lower part of the forearm, and stands out when the little finger is strongly abducted.

The elevation on the lateral side of the cubital fossa is produced by the Brachioradialis, the extensors, and the Supinator; it occupies the lateral and a considerable part of the dorsal surface of the forearm in the region of the elbow, and appears as a fusiform swelling which is on a higher level than that produced by the medial elevation. Its apex is between the Triceps brachii and Brachialis some distance above the elbow-joint; its greatest breadth is opposite the lateral epicondyle; below this it shades off into a flattened surface. About the middle of the forearm a furrow divides it into a lateral and a medial eminence. The lateral eminence consists of the *Brachioradialis,* the *Extensor carpi radialis longus* and the *Extensor carpi radialis brevis.* The medial border of the Brachioradialis starts as a rounded elevation above the lateral epicondyle; lower down, the muscle forms a prominent

mass on the radial side of the upper part of the forearm; below, it tapers to its tendon which may be traced to the base of the styloid process of the radius. The medial eminence comprises the *Extensor digitorum communis*, *Extensor digiti quinti proprius*, and the *Extensor carpi ulnaris*; it begins at the lateral epicondyle of the humerus as a tapering mass which is separated above from the Anconæus by a well-marked groove, and below from the Flexor carpi ulnaris by the ulnar furrow. The *Anconæus* produces a triangular, slightly elevated area, immediately lateral to the subcutaneous surface of the olecranon and separated from the extensor group by an oblique depression; the upper angle of the triangle is at the dimple behind the lateral epicondyle.

At the lower part of the back of the forearm in the interval between the lateral and medial eminences is an oblique elongated swelling, full above but flattened and partially subdivided below; it is caused by the *Abductor pollicis longus* and the *Extensor pollicis brevis*. It crosses the dorsal and lateral surfaces of the radius to the lateral side of the wrist-joint, whence it is continued to the dorsal surface of the thumb as a ridge which is best marked when the thumb is extended.

The tendons of most of the extensor muscles can be seen and felt on the back of the wrist. Laterally is the oblique ridge produced by the Extensor pollicis longus; it may be followed from the ridge on the dorsal surface of the lower end of the radius to the base of the distal phalanx of the thumb. When the wrist is extended the Extensor carpi radialis longus and the Extensor carpi radialis brevis can be identified running side by side from the lateral edge of the ridge on the dorsal surface of the lower end of the radius to the bases of the second and third metacarpal bones. Medial to these the extensor tendons of the fingers can be felt, the Extensor digiti quinti proprius being separated from those of the Extensor digitorum communis by a slight furrow.

The muscles of the hand are principally concerned, as regards surface form, in producing the thenar and hypothenar eminences, and cannot be individually distinguished; the thenar eminence, on the lateral side, is larger and rounder then the hypothenar, which is a long narrow elevation along the medial side of the palm. When the *Palmaris brevis* is in action it produces a wrinkling of the skin over the proximal part of the hypothenar eminence and a dimple on the medial border of the hand. On the back of the hand the *Interossei dorsales* fill the intervals between the metacarpal bones; the first forms a prominent fusiform bulging when the thumb is adducted.

The **arteries.**—Above the middle of the clavicle the pulsation of the *subclavian artery* can be detected by pressing downwards, backwards, and medialwards against the first rib. The pulsation of the *axillary artery*, where the vessel crosses the second rib, can be felt below the middle of the clavicle medial to the coracoid process; along the lateral wall of the axilla the course of the artery can be easily followed close to the medial border of the Coracobrachialis. The pulsation of the *brachial artery* can be recognised and the thickness of the vessel wall determined in the greater part of its course as it lies along the medial margin of the Biceps brachii; in the upper two-thirds of the arm it lies on the medial side of the humerus, but in the lower one-third is more directly in front of the bone. In front of the lower end of the radius, between the styloid process and Flexor carpi radialis, a portion of the *radial artery* is superficial and is used clinically for observations on the pulse.

The **veins.**—The superficial veins of the upper extremity are easily rendered visible by compressing the proximal trunks near the axilla; their arrangement is described on pp. 724 to 727.

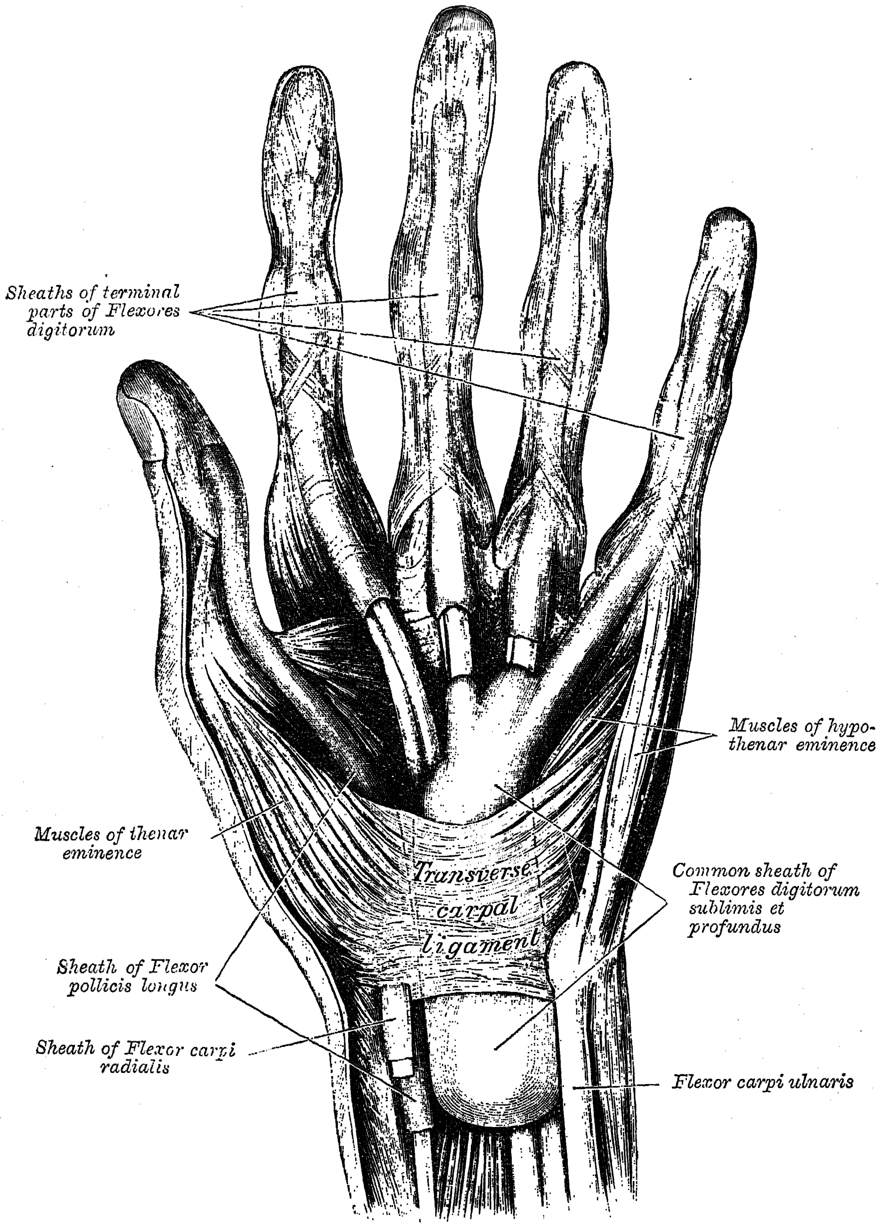
The **nerves.**—The uppermost trunks of the *brachial plexus* can be felt for a short distance above the clavicle as they emerge from under the lateral border of Sternocleidomastoideus; the larger nerves derived from the plexus can be rolled under the finger against the lateral axillary wall, but cannot be separately identified. The *ulnar nerve* can be detected in the sulcus nervi ulnaris behind the medial epicondyle of the humerus, but is more easily felt about 2 cm. below the elbow-joint.

THE SURFACE MARKINGS OF THE UPPER EXTREMITY

The **bony landmarks.**—The bony landmarks as described above are so readily available for surface recognition that no special measurements are required to indicate them. It may be noted, however, that the medial angle of the scapula

is applied to the second rib, while the inferior angle lies against the seventh. The intertubercular sulcus of the humerus is vertically below the acromioclavicular joint when the arm hangs by the side of the body with the palm of the hand forwards.

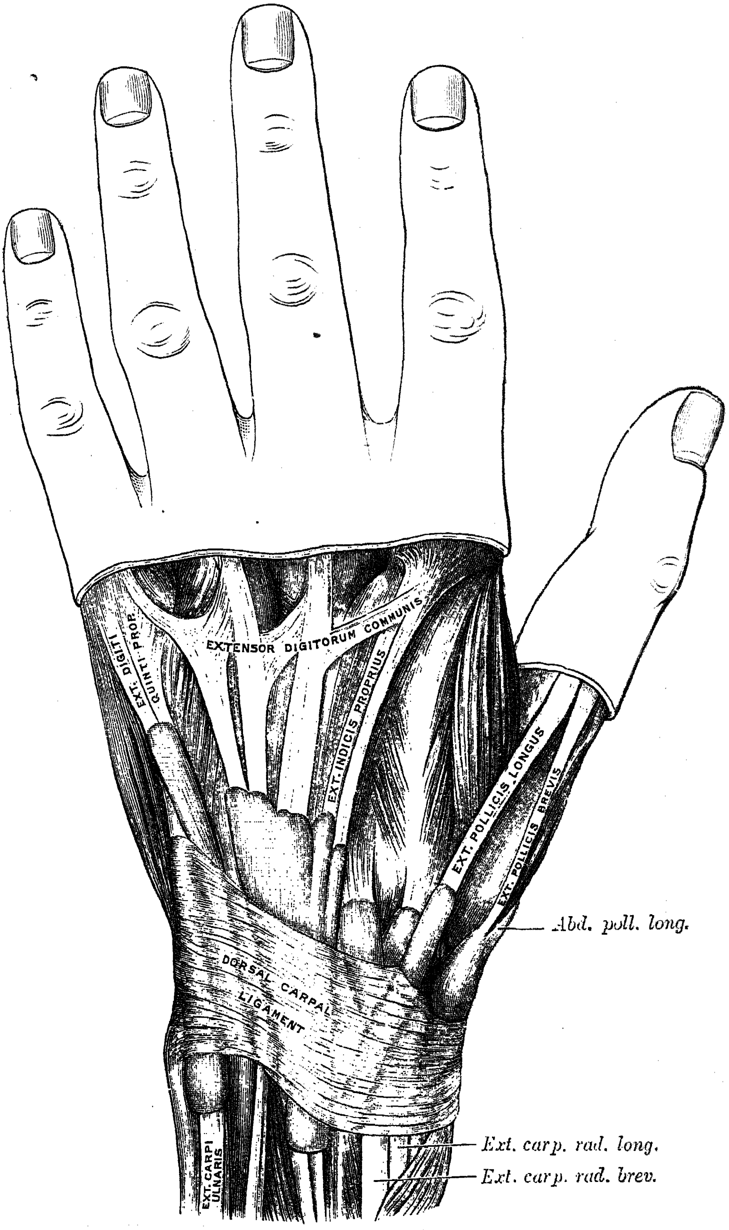
FIG. 1252.—The mucous sheaths of the tendons on the front of the wrist and digits. (From a preparation by J. C. B. Grant.)



The **articulations.**—The *acromioclavicular joint* is situated in a plane passing sagitally through the middle line of the front of the arm. The line of the *elbow-joint* is not straight; the humeroradial portion is practically at right angles to the long axis of the humerus, and is situated about 2 cm. distal to the lateral epicondyle; the humero-ulnar portion is oblique, and its medial end is about 2·5 cm. distal to the medial epicondyle. The position of the *wrist-joint* can be indicated by

drawing a curved line, with its convexity upwards, between the styloid processes of the radius and ulna; the summit of the convexity is about 1 cm. above the centre of a straight line joining the two processes.

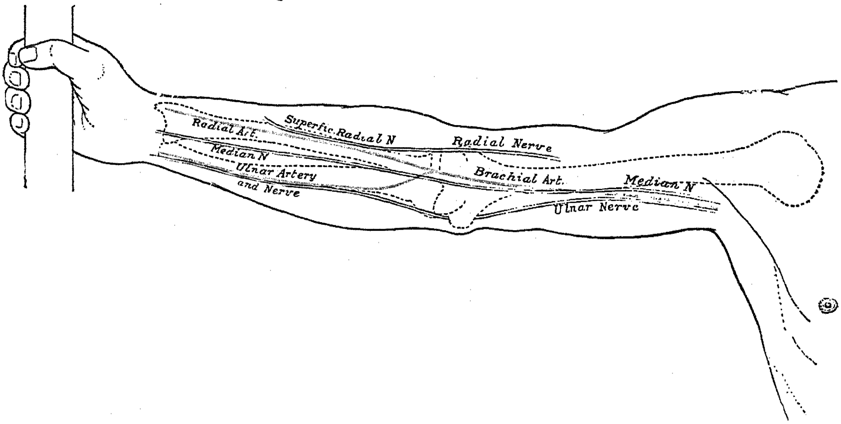
Fig. 1253.—The mucous sheaths of the tendons on the back of the wrist. (From a preparation by J. C. B. Grant.)



The **muscles.**—The only muscles of the upper extremity which occasionally require definition by surface lines are the Trapezius, the Latissimus dorsi and the Pectorales major et minor. The anterosuperior border of the *Trapezius* is indicated by a line from a point about 3 cm. lateral to the external occipital protuberance to the junction of the intermediate with the lateral one-third of the clavicle; the line of the lower border extends from the spinous process of the twelfth thoracic

vertebra to the root of the spine of the scapula. The upper border of the *Latissimus dorsi* is almost horizontal, running from the spinous process of the seventh thoracic vertebra to the inferior angle of the scapula and thence somewhat obliquely to the intertubercular sulcus of the humerus; the lower border corresponds roughly to a line drawn from the iliac crest about 2 cm. from the lateral margin of the Sacrospinalis to the intertubercular sulcus of the humerus. The upper margin

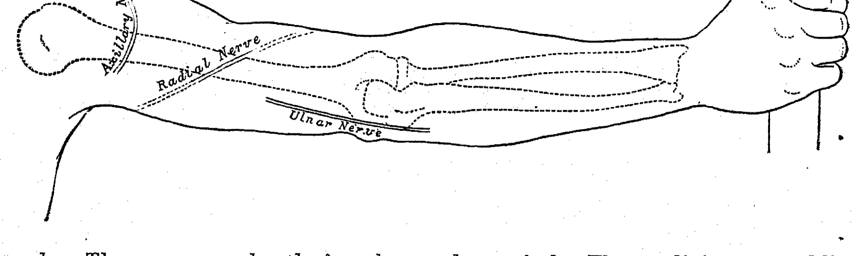
FIG. 1254.—The front of the right upper extremity, showing the surface markings for the bones, arteries, and nerves.



of the *Pectoralis major* extends from the middle of the clavicle to the surgical neck of the humerus; its lower border is practically in the line of the fifth rib and reaches from the fifth costochondral junction to the middle of the anterior border of the Deltoideus. The lines indicating the upper and lower borders of the *Pectoralis minor* begin at the coracoid process of the scapula and extend to the third and fifth ribs respectively, just lateral to the corresponding costal cartilages. On the front of the elbow-joint a triangular space—the cubital fossa—is mapped out for convenience of reference. The base of the triangle is a line joining the medial and lateral epicondyles of the humerus, while the sides are formed respectively by the salient margins of the Brachioradialis and Pronator teres.

The **mucous sheaths.**—On the volar surfaces of the wrist and hand the mucous sheaths of the flexor tendons (fig. 1252) can be indicated as follows. The sheath for the Flexor pollicis longus extends from a point about 3 cm. above the upper edge of the transverse carpal ligament to the base of the terminal phalanx of the

FIG. 1255.—The back of the right upper extremity, showing the surface markings for the bones and nerves.

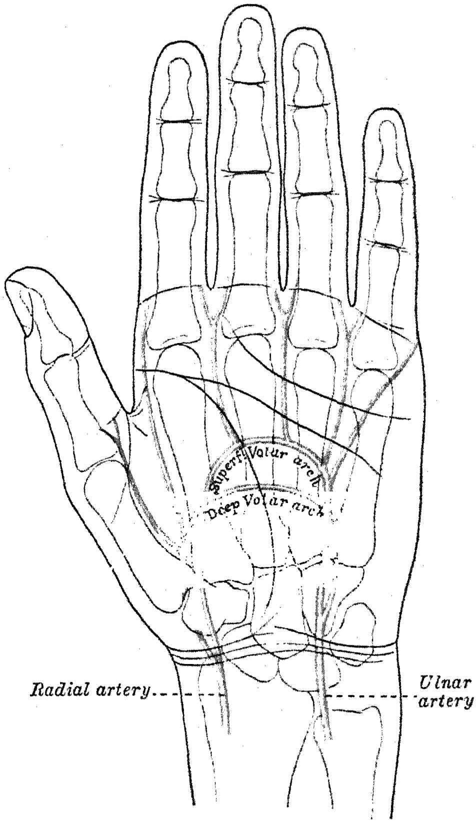


thumb. The common sheath for the tendons of the Flexor digitorum sublimis and Flexor digitorum profundus reaches about 4 cm. above the upper edge of the transverse carpal ligament and extends into the palm to about the level of the centres of the metacarpal bones. The sheath for the tendons to the little finger is continued from the common sheath to the base of the terminal phalanx of this finger; the sheaths of the tendons to the index, middle and ring fingers are separated from the common sheath by an interval; they begin opposite the necks of

the metacarpal bones and extend to the bases of the terminal phalanges. The mucous sheaths of the extensor tendons are shown in fig. 1253 (see also p. 519).

The **arteries** (fig. 1254).—The course of the *axillary artery* can be indicated by raising the arm to the level of the shoulder and drawing a line from the middle of the clavicle to the point where the tendon of the Pectoralis major crosses the prominence of the Coracobrachialis. The origin of the *thoraco-acromial artery* corresponds to the point where the axillary artery is crossed by the upper border of the Pectoralis minor; the *lateral thoracic artery* follows the line of the lower border of the Pectoralis minor; the *subscapular artery* is sufficiently indicated by the axillary border of the scapula; the *scapular circumflex artery* rises from the subscapular artery opposite the midpoint of a line joining the tip of the acromion to the lower edge of the deltoid tuberosity, or, alternatively, from a point on the axillary border of the scapula 5 cm. from the inferior angle; the *humeral circumflex arteries* arise from the axillary artery about 2 cm. above this. The course of the *brachial artery* is marked by a line drawn from the medial border of the Coracobrachialis at the level of the posterior axillary fold to a point in front of the elbow-joint midway between the epicondyles of the humerus, and continued distally for 2·5 cm., where the artery bifurcates. The *arteria profunda brachii* crosses the back of the humerus at the level of the insertion of Deltoideus; the *nutrient artery* of the humerus arises opposite the middle of the body of the bone; a line from this point to the back of the medial epicondyle represents the *superior ulnar collateral artery*; the *inferior ulnar collateral artery* arises about 5 cm. above the fold of the elbow-joint and runs medialwards.

FIG. 1256.—The palm of the left hand, showing the positions of the skin creases and the bones, and the surface markings for the volar arches.



The position of the *radial artery* in the forearm is represented by a line drawn from the lateral margin of the tendon of the Biceps brachii in the centre of the cubital fossa, to the medial side of the front of the styloid process of the radius. The situation of the distal portion of the artery is indicated by continuing this line round the radial side of the wrist to the proximal end of the first intermetacarpal space.

On account of the curved direction of the *ulnar artery*, two lines are required to indicate its course in the forearm; one is drawn from the front of the medial epicondyle of the humerus to the radial side of the pisiform bone; the distal two-thirds of this line represent the distal two-thirds of the artery; the proximal one-third of the artery is represented by a line, convex medialwards, from the centre of the hollow in front of the elbow-joint to the junction of the upper with the middle one-third of the first line.

The position of the *superficial volar arch* (fig. 1256) is indicated by a curved line starting from the radial side of the pisiform bone, running distalwards for about one-half of the length of the palm, then lateralwards as far as the base of the thumb, and finally proximalwards towards the middle of the thenar eminence. The summit of the arch is usually on a level with the distal border of the outstretched

thumb. The *deep volar arch* is transverse in direction, and is situated about 1 cm. nearer to the carpus.

The **nerves** (figs. 1254, 1255).—In the arm the line of the *median nerve* is that for the brachial artery; at the upper part of the arm it is lateral to the artery, whereas at the bend of the elbow it is medial to it. The course of the nerve in the forearm is marked by a line starting from a point just medial to the centre of one joining the humeral epicondyles, or midway between the medial epicondyle and the tendon of Biceps brachii, and extending to the middle of the front of the wrist where it lies deep to the tendon of the Palmaris longus.

The *ulnar nerve* follows the line of the brachial artery in the upper half of the arm, but at the middle of the arm it leaves the artery and descends to the back of the medial epicondyle. In the forearm it is represented by a line from the front of the medial epicondyle to the lateral side of the pisiform bone.

The course of the *radial nerve* can be indicated by a line drawn from just below the posterior axillary fold, to the lateral side of the humerus at the junction of its middle with its lower one-third; thence it passes vertically downwards on the front of the arm to the level of the lateral epicondyle. The course of the *superficial radial nerve* is represented by a continuation of this line to the junction of the middle with the lower one-third of the radius; it then crosses the lateral border of the radius and runs distalwards to the dorsum of the base of the first metacarpal bone.

The *axillary nerve* crosses the humerus about 2 cm. above the centre of a line joining the tip of the acromion to the lower edge of the deltoid tuberosity.

THE SURFACE ANATOMY OF THE LOWER EXTREMITY

The **skin.**—The skin on the medial side of the thigh and in the hollow of the groin is thin, smooth, and elastic, and contains few hairs except in the neighbourhood of the os pubis; on the lateral side of the thigh it is thicker, and the hairs are more numerous. At the junction of the front of the thigh with the abdomen is a well-defined furrow which indicates the site of the inguinal ligament; the furrow presents a general convexity downwards, but its medial half, which is the better marked, is nearly straight. The skin of the buttock is fairly thick and as a rule is destitute of conspicuous hairs except towards the post-anal furrow, where in some males they are abundantly developed. An almost transverse fold—the *fold of the buttock* or *glutæal fold*—crosses the lower part of the buttock; it practically bisects the lower margin of the Glutæus maximus and is most evident when the hip-joint is extended. The skin over the front of the knee is covered by thickened epidermis; it is loose and is thrown into transverse wrinkles when the leg is extended. The skin of the leg is thin, especially on the medial side, and is covered with numerous large hairs. On the dorsum of the foot the skin is thin, loosely connected to subjacent parts, and contains few hairs; on the plantar surface, and especially over the heel, the epidermis is of great thickness, and here, as in the palm of the hand, there are neither hairs nor sebaceous glands.

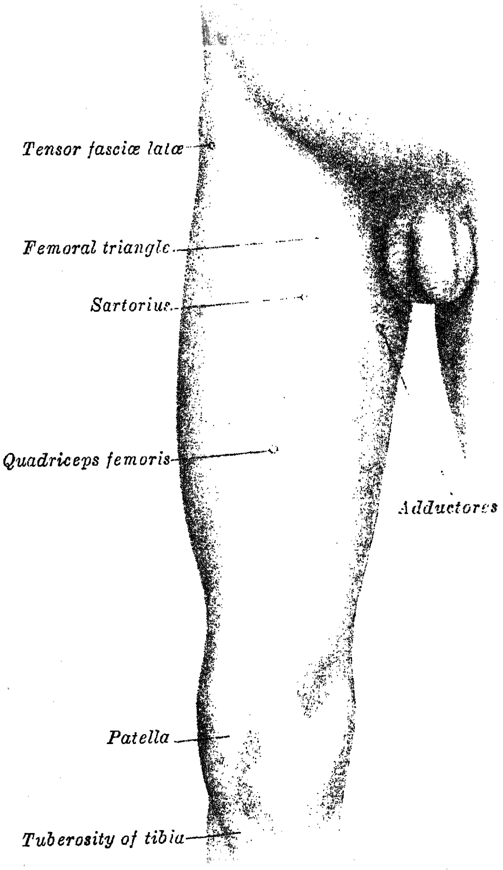
The **bones.**—The *hip-bones* are largely covered with muscles, and only approach the surface at a few points. In front, the anterior superior iliac spine is easily recognised, and in thin subjects stands out as a prominence at the lateral end of the fold of the groin; in fat subjects its position is indicated by an oblique depression, at the bottom of which the bony process can be felt. Proceeding upwards and backwards from the anterior superior iliac spine the sinuously curved iliac crest can be traced to the posterior superior iliac spine, the site of which is indicated by a slight depression; on the outer lip of the crest, about 5 cm. behind the anterior superior spine, is the iliac tubercle. In thin subjects the pubic tubercle is very apparent, but in the obese it is obscured by the pubic fat; it can, however, be detected by following the tendon of origin of the Adductor longus. Another part of the hip-bone which is accessible to touch is the ischial tuberosity, situated beneath the Glutæus maximus and easily felt when the hip-joint is flexed, as it is then uncovered by muscle. On the boundary of the perinæum the whole outline of the pubic arch can be recognised.

The *femur* is enveloped by muscles, so that the only subcutaneous parts of it are the lateral surface of the greater trochanter and the lower expanded end of

the bone. The site of the greater trochanter is generally indicated by a depression owing to the thickness of the Glutæus medius and Glutæus minimus which project above it; when, however, the thigh is flexed, and especially if it be crossed over the opposite one, the trochanter produces a blunt eminence on the surface. The condyles and epicondyles can be readily identified, and at the upper part of the medial condyle the sharp adductor tubercle can be recognised without difficulty. When the knee is flexed the upper portion of the patellar surface of the femur is palpable above the patella.

The anterior surface of the *patella* is subcutaneous. When the knee is extended the medial border of the bone is a little more prominent than the lateral, and if the Quadriceps femoris be relaxed the bone can be moved from side to side. When the joint is flexed the patella recedes into the hollow between the femoral condyles and the upper end of the tibia, and is firmly applied to the femur.

Fig. 1257.—The front and medial surface of the right thigh.



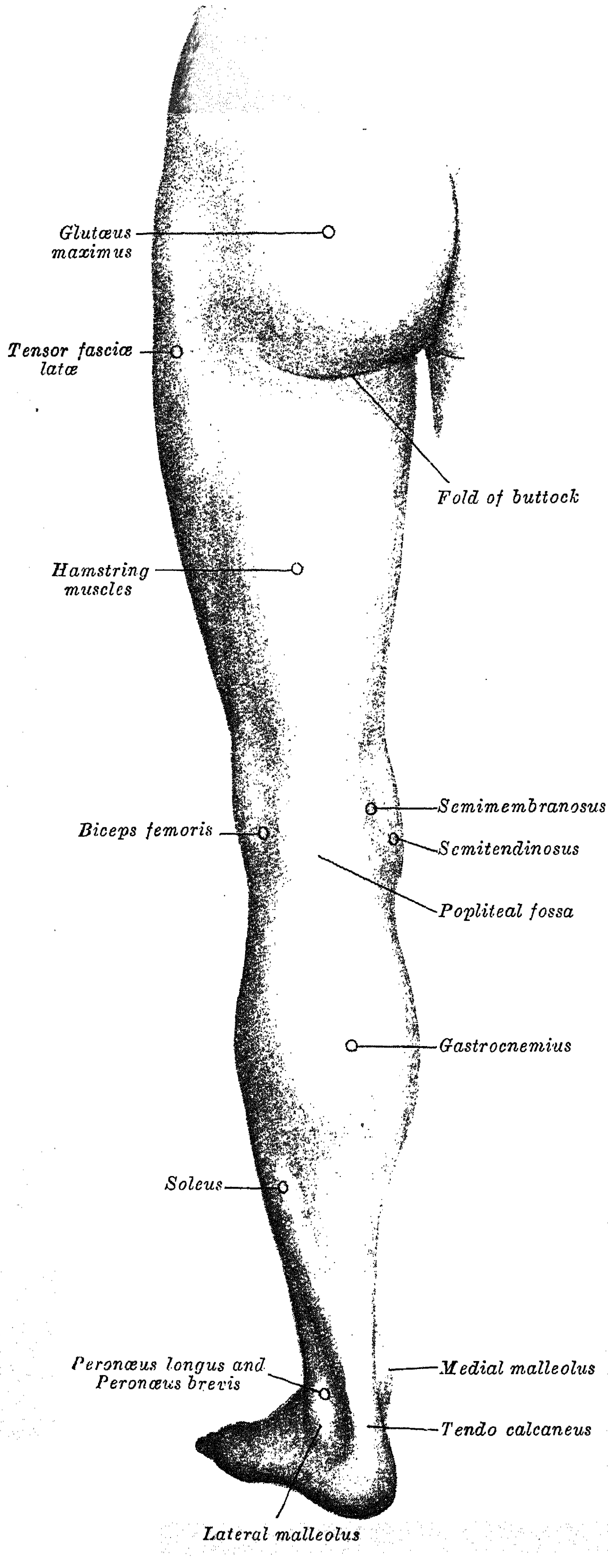
A considerable portion of the *tibia* is subcutaneous. At the upper end the condyles can be felt just below the knee; the medial condyle is broad and smooth, and merges below into the subcutaneous surface of the body or shaft of the bone; the lateral is narrower and more prominent, and on it, about midway between the apex of the patella and the head of the fibula, is the tubercle for the attachment of the iliotibial tract of the fascia lata of the thigh. In front of the upper end of the bone, between the condyles, is the tuberosity, which is continuous below with the anterior crest of the bone. This crest is subcutaneous throughout; it is sharp in its upper three-fourths but more rounded below where it ultimately becomes continuous with the anterior border of the medial malleolus. Medial to the anterior crest is the broad subcutaneous surface. The medial malleolus forms a broad prominence, situated at a higher level and somewhat farther forward than the lateral malleolus; its anterior border is nearly straight; on its posterior is a sharp edge which forms the medial margin of the groove for the tendon of the Tibialis posterior.

The only subcutaneous parts of the *fibula* are the head, the lower part of the body or shaft, and the lateral malleolus. The head lies behind and lateral to the lateral condyle of the tibia, and appears as a small prominent pyramidal eminence slightly above the level of the tibial tuberosity; its position can be located by following the tendon of Biceps femoris downwards. The lateral malleolus is a narrow elongated prominence from which the lower one-third or half of the lateral surface of the body of the bone can be traced upwards.

On the dorsum of the tarsus the individual bones cannot be distinguished, with the exception of the head of the *talus* which forms a rounded projection in front of the ankle-joint when the foot is extended. The whole dorsal surface of the foot

has a smooth convex outline, the summit of which is the ridge formed by the head of the talus, the navicular, the second cuneiform, and the second metatarsal bone; from this it inclines gradually lateralwards, and rapidly medialwards. On the medial side of the foot the medial process of the tuberosity of the *calcaneus* and the ridge separating the posterior from the medial surface of the bone are distinguishable; in front of this, and 2 cm. below the medial malleolus, is the sustentaculum tali. The tuberosity of the *navicular* is palpable about 2·5 cm. in front of the sustentaculum tali.

FIG. 1258.—The back of the left lower extremity.



Farther forwards, the ridge formed by the base of the *first metatarsal bone* can be obscurely felt, and from this the body of the bone can be traced to the expanded head; beneath the head is the medial sesamoid bone. On the lateral side of the foot, the most posterior bony point is the lateral process of the tuberosity of the calcaneus, with the ridge separating the posterior from the lateral surface of the bone. In front of this the greater part of the lateral surface of the calcaneus is subcutaneous; on it, below and in front of the lateral malleolus, the trochlear process, when present, can be felt. Farther forwards. the base of the *fifth metatarsal bone* is prominent, and from it the body of the bone can be traced forwards to the head.

As in the case of the metacarpals, the dorsal surfaces of the *metatarsal bones* are easily defined, although their heads do not form prominences;

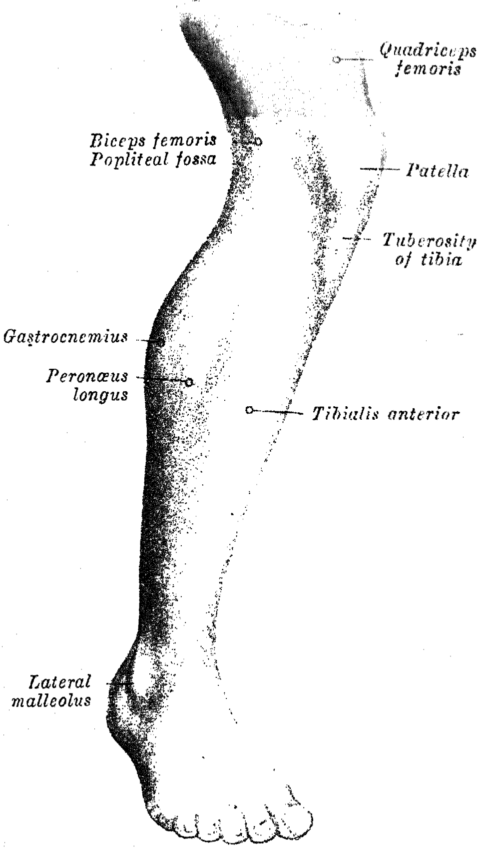
the plantar surfaces are obscured by muscles. The *phalanges* in their whole extent are readily palpable.

The **articulations.**—The *hip-joint* is deeply seated and cannot be palpated.

The interval between the tibia and femur, indicating the level of the *knee-joint*, can always be easily felt. When the knee is semi-flexed, the medial border of the patella, the medial condyle of the femur, and the upper border of the medial condyle of the tibia, bound a triangular depressed area which indicates the position of the joint and is in front of the anterior end of the medial meniscus.

The *ankle-joint* can be felt in the hollows between the extensor tendons and the medial and lateral malleoli; during extension of the joint the superior articular surface of the talus projects below the anterior border of the lower end of the tibia.

Fig. 1259.—The lateral surface of the right leg.



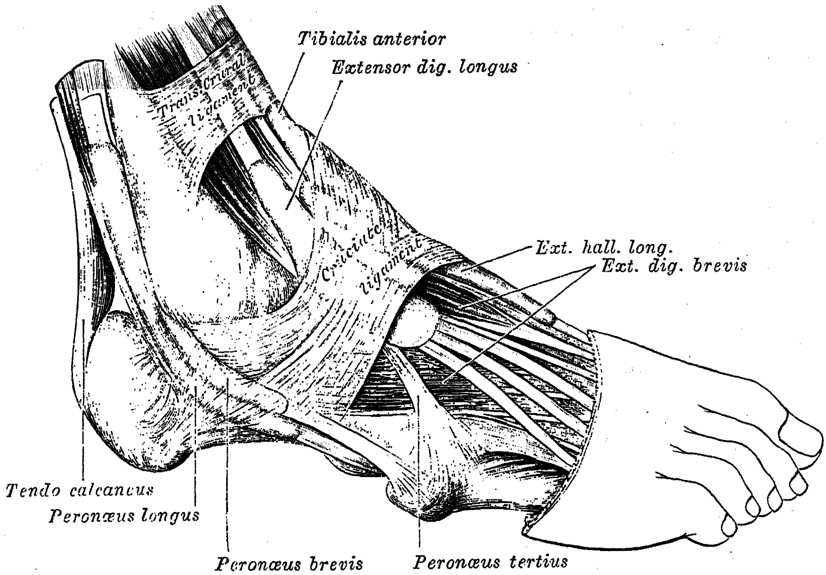
The *metatarsophalangeal and interphalangeal joints* are all palpable.

The **muscles.**—Of the muscles of the thigh, those of the anterior femoral region (fig. 1257) contribute largely to surface form. The *Tensor fasciæ latæ* produces an elevation immediately below the anterior part of the iliac crest and above and in front of the greater trochanter of the femur; it is most apparent in standing on one leg; from its lower border a groove caused by the iliotibial tract of the fascia lata extends downwards to the lateral side of the knee-joint. At the knee-joint the *iliotibial tract* forms a prominent band between the head of the fibula and the lateral margin of the patella; it is parallel with, and a finger's breadth in front of, the tendon of the Biceps femoris. The upper portion of the *Sartorius* constitutes the lateral boundary of the femoral triangle, and, when the muscle is in action, forms a prominent oblique ridge which is continued below into a flattened plane and then gradually merges into a general fulness on the medial side of the knee-joint. When the Sartorius is not in action, a depression exists between the Quadriceps femoris and the Adductores and extends obliquely downwards and medialwards from the apex of the femoral triangle to the side of the knee. In the angle between the Sartorius and Tensor fasciæ latæ, just below the anterior superior iliac spine, the *Rectus femoris* appears, and its borders can be defined when the muscle is in action. The *Vastus lateralis* forms a long flattened plane traversed by the groove of the iliotibial tract. The *Vastus medialis* causes a considerable prominence on the medial side of the lower half of the thigh; this prominence increases towards the knee and ends somewhat abruptly with a full curved outline. The *Vastus intermedius* is completely hidden. The Adductores cannot be differentiated from one another, with the exception of the tendon of origin of the Adductor longus and the lower tendon of the Adductor magnus. When the *Adductor longus* is in action, or when the limb is passively abducted, its tendon of origin stands out as a prominent ridge running obliquely downwards and lateralwards from the neighbourhood of the pubic tubercle, and forming the medial border of the

femoral triangle. The lower tendon of the *Adductor magnus* is felt as a short ridge extending downwards between the Sartorius and Vastus medialis to the adductor tubercle on the medial condyle of the femur. The Adductores fill the triangular space at the upper part of the thigh, between the femur and the pelvis, and to them is due the contour of the medial border of the thigh, the *Gracilis* contributing largely to the smoothness of the outline.

The *Glutæus maximus* (fig. 1258), prominent behind, compressed in front, forms the full rounded outline of the buttock; its lower border runs from the side of the coccyx, over the ischial tuberosity, to about 9 cm. below the greater trochanter of the femur, and crosses the glutæal fold obliquely downwards and lateralwards; its upper border is ill-defined, the lower part of its medial border is separated from the corresponding part of the opposite muscle by the deep glutæal cleft. The upper part of the *Glutæus medius* is visible above and behind the greater

FIG. 1260.—The mucous sheaths of the tendons round the ankle. Lateral aspect. (From a preparation by J. C. B. Grant.)



trochanter, but its lower part, together with the *Glutæus minimus* and the external rotators of the thigh, is completely hidden by the Glutæus maximus. The hamstring muscles appear from beneath the lower margin of the Glutæus maximus; at first they are narrow and not well defined, but as they descend they become more prominent and eventually divide into two well-marked ridges formed by their tendons; these constitute the upper boundaries of the popliteal fossa. The tendon of the *Biceps femoris* is a thick cord running to the head of the fibula: the tendons of the *Semimembranosus* and *Semitendinosus* run medialwards to the tibia and are separated by a slight furrow; the Semitendinosus is the more superficial, and can be felt in certain positions of the limb as a sharp cord, while the Semimembranosus is thick and rounded. The Gracilis is situated a little in front of them.

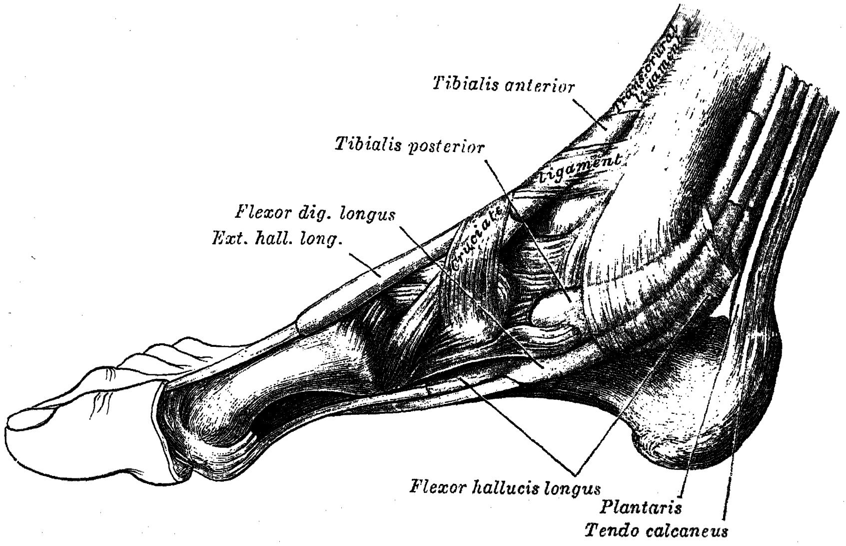
The *Tibialis anterior* (fig. 1259) presents a fusiform enlargement at the lateral side of the tibia and projects beyond the anterior crest of the bone; its tendon can be traced on the front of the tibia and ankle-joint and thence along the medial side of the foot to the base of the first metatarsal bone. The fleshy fibres of the *Peronæus longus* are strongly marked at the upper part of the lateral side of the leg; it is separated by furrows from the Extensor digitorum longus in front and the Soleus behind. Below, the fleshy fibres end abruptly in a tendon which overlaps the more flattened elevation of the *Peronæus brevis*; below the lateral malleolus the tendon of the Peronæus brevis is the more marked and can be traced to the base of the fifth metatarsal bone.

On the dorsum of the foot (fig. 1260) the tendons emerging from beneath the

transverse and cruciate crural ligaments spread out and can be distinguished as follows: the most medial and largest is the Tibialis anterior, the next is the Extensor hallucis proprius, then the Extensor digitorum longus dividing into four tendons to the second, third, fourth, and fifth toes, and lastly the Peronæus tertius. The *Extensor digitorum brevis* produces a rounded outline on the dorsum of the foot and a fulness in front of the lateral malleolus. The *Interossei dorsales* intervene between the metatarsal bones.

At the back of the knee is the popliteal fossa, bounded above by the tendons of the hamstrings and below by the Gastrocnemius. Below this fossa is the prominent fleshy mass of the calf of the leg produced by the Gastrocnemius and Soleus (fig. 1258). When these muscles are in action the borders of the *Gastrocnemius* form two well-defined curved lines which converge to the tendo calcaneus; the medial border is the more prominent. At the same time the edges of the *Soleus* form, on

Fig. 1261.—The mucous sheaths of the tendons round the ankle. Medial aspect. (From a preparation by J. C. B. Grant.)



either side of the Gastrocnemius, curved eminences, of which the lateral is the longer. The fleshy mass of the calf ends somewhat abruptly in the tendo calcaneus, which tapers in the upper three-fourths of its extent but widens out slightly below. When the *Tibialis posterior* is in action, its tendon produces a well-defined ridge between the medial border of the lower part of the tibia and the tuberosity of the navicular bone; the tendon may be followed upwards behind the medial malleolus for a distance of about 5 cm.

On the sole of the foot the *Abductor digiti quinti* forms a narrow rounded elevation on the lateral side, and the *Abductor hallucis* a lesser elevation on the medial side. The *Flexor digitorum brevis*, bound down by the plantar aponeurosis, is not very apparent.

The **arteries.**—The *femoral artery* is readily felt as it crosses the brim of the pelvis; in its course down the thigh its pulsation becomes gradually more difficult of recognition. When the knee is flexed the pulsation of the *popliteal artery* can easily be detected in the popliteal fossa.

The *anterior tibial artery* is superficial on the lower part of the front of the tibia and can be traced over the ankle into the *dorsalis pedis artery*; the latter can be followed to the proximal end of the first intermetatarsal space. The pulsation of the *posterior tibial artery* is evident near the lower end of the back of the tibia, and is easily detected behind the medial malleolus.

The **veins.**—By compressing the proximal trunks, the venous arch on the dorsum of the foot and the great and small saphenous veins (pp. 733 to 735) are rendered visible.

the fourth interspace of the right side. The lines indicating the atrioventricular orifices are parallel with and slightly below the line of the coronary sulcus.

The **arteries.**—The line of the *ascending aorta* begins slightly to the left of the midsternal line opposite the third costal cartilage, and extends upwards and to the right to the level of the upper border of the second right costal cartilage. The *aortic arch* lies behind the lower half of the manubrium sterni. A line from the middle of the manubrium sterni to the right sternoclavicular articulation represents the site of the *innominate artery,* while another line from a point slightly to the left of the middle of the manubrium sterni to the left sternoclavicular articulation indicates the position of the thoracic part of the *left common carotid artery.*

The *internal mammary artery* descends behind the first six costal cartilages about 1 cm. from the lateral sternal line.

The **veins.**—The line of the *right innominate vein* crosses the sternal end of the right clavicle and the upper border of the first right costal cartilage about 1 cm. from the lateral sternal line; that of the *left innominate vein* extends from the sternal end of the left clavicle to meet the line of the right innominate vein at the upper border of the first right costal cartilage. The junction of the two lines indicates the origin of the *superior vena cava,* and the line of this vessel is continued vertically down to the level of the third right costal cartilage. The *inferior vena cava* opens into the right atrium at the level of the upper margin of the sixth right costal cartilage about 2 cm. from the midsternal line.

THE SURFACE ANATOMY OF THE ABDOMEN

The **skin.**—The skin of the front of the abdomen is thin. In the male it is often thickly clad with hairs, especially towards the lower part of the middle line; in the female the hairs are confined to the pubes. Just below the iliac crest is a shallow groove termed the *iliac furrow,* while in the site of the inguinal ligament a sharper fold known as the *fold of the groin* is easily distinguishable.

After distension of the abdomen from pregnancy or other causes the skin commonly presents transverse white lines which are quite smooth, being destitute of papillæ; these are known as *striæ gravidarum* or *striæ albicantes.* The *linea nigra* of pregnancy is a brown streak in the middle line between the umbilicus and symphysis pubis.

In the middle line of the front of the abdomen is a shallow furrow which extends from the junction between the body of the sternum and the xiphoid process to a short distance below the umbilicus; it corresponds to the linea alba. The umbilicus is situated in the middle line, but varies as regards its height; in an adult subject it is always placed above the middle point of the body, and is slightly below the level of the highest points of the iliac crests.

The **bones.**—The bones in relation with the surface of the abdomen are (1) the lower part of the vertebral column and the lower ribs and (2) the pelvis; the former have already been described (pp. 1272 and 1276), the latter will be considered with the lower limb.

The **muscles** (fig. 1240).—The only muscles of the abdomen which have any considerable influence on surface form are the Obliquus externus abdominis and the Rectus abdominis. The upper digitations of origin of the *Obliquus externus* are well marked and interdigitate with those of the Serratus anterior; the lower are covered by the border of the Latissimus dorsi. The attachment of the Obliquus externus and Obliquus internus to the iliac crest forms a thick oblique roll which determines the iliac furrow. On the front of the lateral region of the abdomen an undulating line sometimes marks the passing of the muscular fibres of the Obliquus externus into its aponeurosis. The posterior margin of the Obliquus externus is frequently separated from the lateral margin of the Latissimus dorsi by a small triangular interval—the *lumbar triangle*—the base of which is formed by the iliac crest, and the floor by the Obliquus internus.

The lateral margin of the *Rectus abdominis* is indicated by the *linea semilunaris,* which is easily defined when the muscle is in action. On the surface of the Rectus are three transverse furrows, the *tendinous inscriptions;* the upper two of these, viz. one opposite, or a little below, the tip of the xiphoid process, and the other

The **articulations.**—The posterior superior iliac spine overlies the centre of the *sacro-iliac articulation.*

The *hip-joint* may be indicated, as described above, by the centre of a horizontal line drawn from the pubic tubercle to the top of the greater trochanter; or by a point below and slightly lateral to the middle of the inguinal ligament. The *knee-joint* is superficial and requires no surface marking. The level of the *ankle-joint* is that of a transverse line about 1 cm. above the level of the tip of the medial malleolus. If the foot be extended, the head of the talus appears as a

FIG. 1263.—The front of the right thigh, showing the surface markings for the bones, the femoral artery, and the femoral nerve.

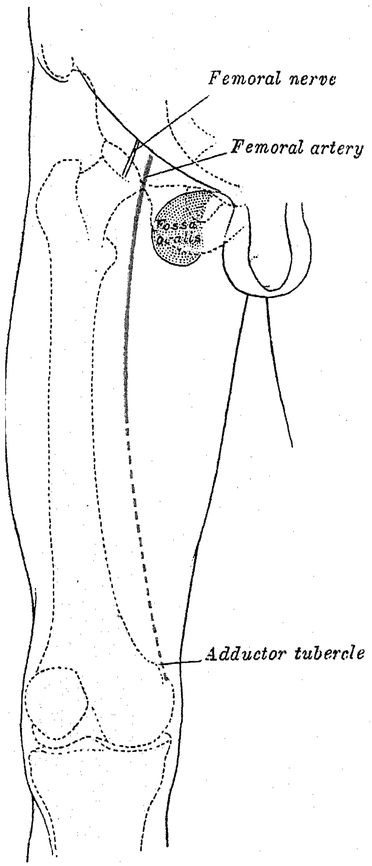
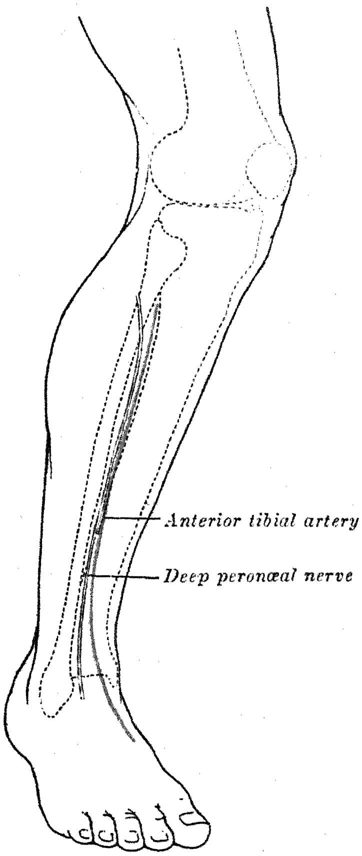
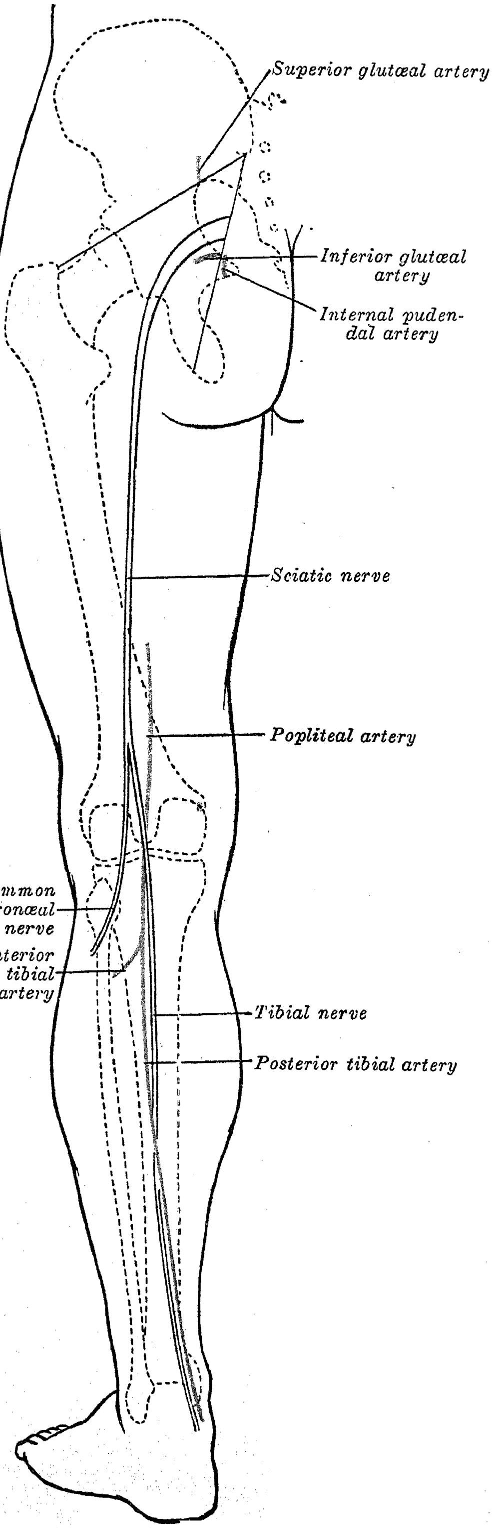


FIG. 1264.—The lateral aspect of the right leg, showing the surface markings for the bones, the anterior tibial and dorsalis pedis arteries, and the deep peronæal nerve.



rounded prominence on the medial side of the dorsum; between it and the tuberosity of the navicular is the *talonavicular joint.* The *calcaneocuboid joint* is midway between the lateral malleolus and the prominent base of the fifth metatarsal bone; the line indicating it is parallel to that of the talonavicular joint. The line of the *fifth tarsometatarsal joint* is very oblique; it starts behind the projection of the base of the fifth metatarsal bone, and if continued would pass through the head of the first metatarsal bone. The lines of the *fourth* and *third tarsometatarsal joints* are less oblique. The *first tarsometatarsal joint* corresponds to a groove which can be felt by making firm pressure on the medial border of the foot 2·5 cm. in front of the tuberosity of the navicular; the position of the *second tarsometatarsal joint* is 1·25 cm. behind this. The *metatarsophalangeal joints* are about 2·5 cm. behind the webs of the corresponding toes.

FIG. 1265.—The back of the left lower extremity, showing the surface markings for the bones, vessels, and nerves.



The **muscles.**—The muscles do not require surface lines to indicate them, but there are three intermuscular spaces which must be identified, viz.: the femoral triangle, the adductor canal, and the popliteal fossa.

The *femoral triangle* is bounded above by the inguinal ligament, laterally by the medial border of the Sartorius, and medially by the medial border of the Adductor longus. In the triangle is the fossa ovalis (saphenous opening), through which the great saphenous vein dips to join the femoral; the centre of this fossa is about 4 cm. below and lateral to the pubic tubercle, its vertical diameter measures about 4 cm. and its transverse about 1·5 cm. The centre of the femoral ring is about 1·25 cm. lateral to the pubic tubercle.

The *adductor canal* occupies the medial part of the middle third of the thigh; it begins at the apex of the femoral triangle and lies deep to the vertical part of the Sartorius. The *popliteal fossa* is bounded, above and medially by the tendons of the Semimembranosus and Semitendinosus, above and laterally by the tendon of the Biceps femoris, below and medially by the medial head of the Gastrocnemius, below and laterally by the lateral head of the Gastrocnemius and the Plantaris.

The **mucous sheaths.**—The positions of the mucous sheaths of the tendons round the ankle-joint are sufficiently indicated in figs. 1260, 1261 (see also p. 560).

The **arteries.**—The points of emergence of the three main arteries on the buttock, viz. the superior and inferior glutæal arteries and the internal pudendal artery, may be indicated in the following manner (fig. 1265). With the femur slightly flexed and rotated inwards, a line is drawn from the posterior superior iliac spine to the posterior superior angle of the greater trochanter;

the point of emergence of the *superior glutæal artery* from the upper part of the greater sciatic foramen corresponds to the junction of the upper with the middle one-third of this line. A second line is drawn from the posterior superior iliac spine to the outer part of the ischial tuberosity; the point of emergence of the *inferior glutæal* and *internal pudendal arteries* from the lower part of the greater sciatic foramen corresponds to the junction of its middle with its lower one-third. The course of the *femoral artery* (fig. 1263) is represented by the upper two-thirds of a line drawn from a point midway between the anterior superior iliac spine and the symphysis pubis to the adductor tubercle of the femur, with the thigh abducted and rotated outwards; the *arteria profunda femoris* rises from the femoral artery about 3 cm. below the inguinal ligament. The course of the upper part of the *popliteal artery* (fig. 1265) is indicated by a line drawn from the lateral margin of the Semimembranosus at the junction of the middle with the lower one-third of the thigh to the middle of the popliteal fossa; from this point it runs vertically downwards to the level of a line drawn through the lower part of the tibial tuberosity. The line indicating the *anterior tibial artery* (fig. 1264) is drawn from the medial side of the head of the fibula to a point midway between the malleoli; the artery begins about 3 cm. below the head of the fibula. The *dorsalis pedis artery* is represented by a line drawn from a point midway between the malleoli to the proximal end of the first intermetatarsal space.

The course of the *posterior tibial artery* (fig. 1265) can be shown by a line drawn from the end of the popliteal artery, i.e. 2·5 cm. below the centre of the popliteal fossa, to midway between the tip of the medial malleolus and the medial margin of the tendo calcaneus; its main branch, the *peronæal artery*, begins about 7 or 8 cm. below the level of the knee-joint and follows the line of the fibula to the back of the inferior tibio-fibular joint. The *medial* and *lateral plantar arteries* begin from the end of the posterior tibial; the medial extends to the middle of the ball of the great toe, the lateral to a finger's breadth medial to the tuberosity of the fifth metatarsal bone; from this latter point the *plantar arch* crosses the foot to the proximal end of the first intermetatarsal space.

The **veins.**—The line of the *great saphenous vein* is drawn from the front of the medial malleolus along the medial margin of the tibia to the adductor tubercle, and thence to the centre of the fossa ovalis (saphenous opening); the *small saphenous vein* runs upwards from the back of the lateral malleolus to the centre of the popliteal fossa.

The **nerves.**—When the thigh is rotated outwards the course of the *sciatic nerve* (fig. 1265) can be indicated by a line drawn from a point about midway between the outer border of the ischial tuberosity and the posterior superior angle of the greater trochanter to the upper angle of the popliteal fossa. The continuation of this line vertically through the centre of the popliteal fossa represents the position of the upper part of the *tibial nerve*, while the *common peronæal nerve* follows the line of the tendon of the Biceps femoris. The line for the *deep peronæal nerve* corresponds with that of the anterior tibial artery, and the line for the lower part of the *tibial nerve* to that of the posterior tibial artery.

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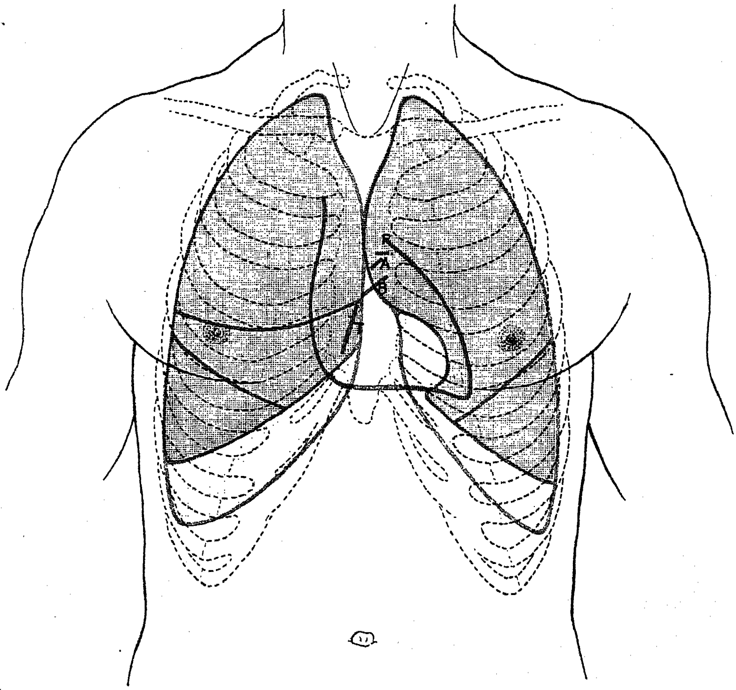
The jugular notch is at the level of the lower border of the body of the second thoracic vertebra, and the sternal angle at the level of the fibrocartilage between the fourth and fifth; the junction between the body and xiphoid process of the sternum corresponds to the fibrocartilage between the ninth and tenth thoracic vertebræ.

The degree of obliquity of the ribs is such that 'if a horizontal line be drawn round the body at the level of the inferior angle of the scapula, while the arms are at the sides, the line would cut the sternum in front between the fourth and fifth ribs, the fifth rib in the nipple line and the ninth rib at the vertebral column.' (Treves.)

The **Diaphragm.**—The shape and variations of the Diaphragm as seen by skiagraphy have already been described (p. 467).

FIG. 1238.—The front of the thorax, showing the surface relations of the bones, lungs (purple), pleuræ (blue), and heart (red outline).



A. Aortic valve. P. Pulmonary valve.
B. Bicuspid or mitral valve. T. Tricuspid valve.

The **surface lines.**—For clinical purposes, and for convenience of description, the surface of the thorax has been mapped out by arbitrary lines (fig. 1241). On the front of the thorax the most important vertical lines are the *midsternal* or median line, and the *mammary* line, the latter of which descends vertically from a point midway between the centre of the jugular notch and the tip of the acromion, and, if prolonged, almost corresponds with the lateral line on the front of the abdomen. Other vertical lines are the *lateral sternal* along the sternal margin, and the *parasternal* midway between the lateral sternal and mammary lines.

On either side of the thorax the *anterior and posterior axillary* lines are drawn vertically from the corresponding axillary folds; the *midaxillary* line runs downwards from the apex of the axilla.

On the posterior surface of the thorax the *scapular* line is drawn vertically through the inferior angle of the scapula.

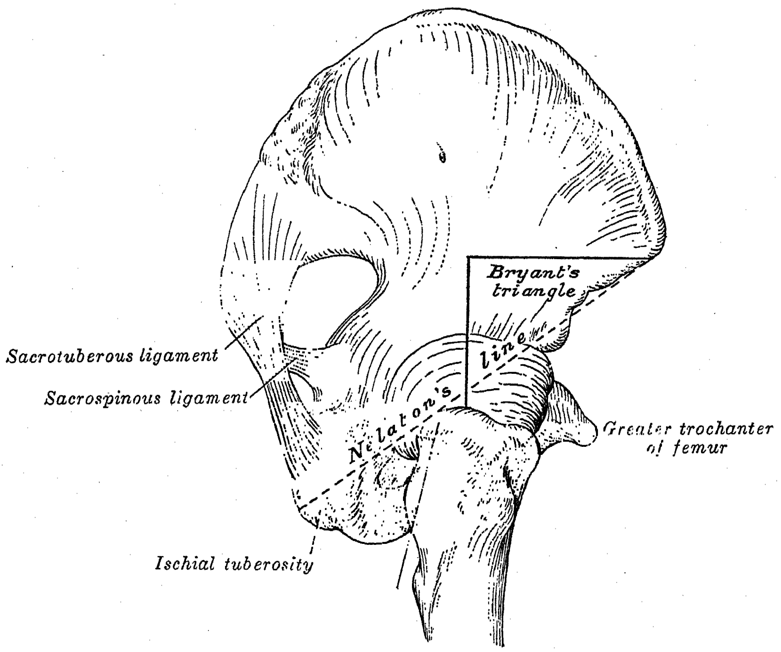
The **pleuræ** (figs. 1237, 1238).—The lines of reflection of the pleuræ can be indicated on the surface. On the *right* side the line passes through the sternoclavicular articulation and runs downwards and medialwards to the midpoint of the

The **nerves.**—The only nerves of the lower extremity which can be located by palpation are (1) the *common peronœal nerve* as it winds round the lateral side of the neck of the fibula, and (2) the *tibial nerve* as it descends behind the lower end of the tibia.

THE SURFACE MARKINGS OF THE LOWER EXTREMITY

The **bony landmarks.**—The anterior superior iliac spine is at the level of the sacral promontory—the posterior at the level of the spinous process of the second sacral vertebra. A horizontal line through the highest points of the iliac crests passes also through the spinous process of the fourth lumbar vertebra, while, as already pointed out (p. 1284), the transtubercular plane through the tubercles on the iliac crests cuts the body of the fifth lumbar vertebra. The upper margin of the greater sciatic notch is opposite the spinous process of the third sacral vertebra, and slightly below this level is the posterior inferior iliac spine. The surface markings of the posterior inferior iliac spine and the ischial spine are in a line which joins

FIG. 1262.—Nélaton's line and Bryant's triangle.



the posterior superior iliac spine to the outer part of the ischial tuberosity; the posterior inferior spine is 5 cm. and the ischial spine 10 cm. below the posterior superior spine; the ischial spine is opposite the first piece of the coccyx.

With the body in the erect posture the line joining the pubic tubercle to the top of the greater trochanter is nearly horizontal; the middle of this line overlies the acetabulum and the head of the femur.

A line used for clinical purposes is that of Nélaton (fig. 1262), which is drawn from the anterior superior iliac spine to the most prominent part of the ischial tuberosity; it crosses the centre of the acetabulum and the upper border of the greater trochanter. Another surface marking of clinical importance is Bryant's triangle, which is mapped out thus: a line from the anterior superior iliac spine to the top of the greater trochanter forms the base of the triangle; its sides are formed respectively by a horizontal line carried backwards from the anterior superior iliac spine and a vertical line from the top of the greater trochanter.